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The Foundry Industry in Ontario

And Outlook for Industrial Minerals

by
Gallagher + Associates
in association with
Robert Shnay Associates and
Stevenson Kellogg Ernst & Whinney

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METRIC CONVERSION FACTORS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in cooperation with the Coal Association of Canada.

The Foundry Industry in Ontario

And Outlook for Industrial Minerals

1. Introduction

This study was commissioned in 1986 by the Ontario Ministry of Northern Development and Mines to examine changes underway in the foundry industry and the implications they might have for industrial minerals. Objectives were established by the Ministry as follows:

- To identify and evaluate needs, issues and trends in the foundry industry in Ontario with implications for industrial minerals.
- To identify and assess opportunities for the development and marketing of competitive, expanded or new uses of provincial mineral resources and products.
- To provide a publishable report primarily intended for mineral producers, processors, industrial raw material researchers and explorationists.

The foundry industry is an important consumer of industrial minerals, most of which are currently supplied by imports from the U.S. It was felt that there are a number of forces that are working to change foundry operations in the province. These were referred to in the terms of reference as follows:

- changing markets, i.e. the decline in 1 to 50 pound castings in the automotive and railroad industries,
- emerging new and improved technologies,
- productivity needs,
- competition with new processes and materials,
- continuing call for better quality and cost effectiveness.

It was reasoned that these and other trends were expected to have a significant impact on raw material supplies that would in turn create new challenges and opportunities for the marketing of provincial mineral resources.

The basic sources of information[1] for this study were the foundries and their mineral suppliers. The following work program was established:

1. Statistical research and preliminary identification of issues.
2. Design of foundry survey questionnaire forms and interview program.
3. Survey of foundries by mail, telephone and personal interviews.
4. Design and implementation of a survey of foundry mineral suppliers.
5. Analysis, report and presentation of findings, conclusions and recommendations.

The following table summarizes those contacted and the responses:

	Mailed/ Contacted	Useful Responses
Foundries:		
Iron	39	34
Steel	14	11
Non-Ferrous	41	20
Total Foundries	94	65
Mineral Suppliers	15	10
Desk Research	15	12
Grand Total	124	87

1. Survey information is current to September, 1986.

2. Structure of the Foundry Industry & its Mineral Suppliers

The foundry industry comprises at least 4 basic metallurgies and upwards of 4 different casting technologies. In addition there are 3 different foundry business or operating strategies and many unique markets. These important structural differences are summarized below.

Metallurgies

- Iron
- Steel
- Aluminum-based
- Copper-based

Technologies

- Sand cast
- Permanent mould
- Investment castings
- Lost foam

Business Strategies

- Captive
- Proprietary products
- Jobbing

Markets

- Auto
- Machinery and equipment
- Pipe and fittings
- Railway
- Plumbing
- Electrical
- and many others.

The industry is extremely heterogeneous, in fact, it is not really an industry. It is a technology, which divides into at least 30 product-market segments. For instance, foundries supplying auto parts, plumbing brass or nuclear valve bodies have little in common. They have not only different metallurgies, technologies, strategies and markets, but also different competitors, cost structures and raw material needs.

Useful survey results were obtained from 65 foundries, who reported data shown in Table 1. Iron foundries dominate the industry in volume of output and number of firms. The best rate of response was obtained from this sector.

It was estimated that Ontario's foundry industry produced castings of all types with a value close to $1.8 billion in 1985. About $1.4 billion was reported by those who responded to our survey, or 79%. The industry operated at a capacity utilization of 72%. This varied widely by sector and by company. Total industry employment in foundry and related operations is estimated at about 13,000. There are about 150 foundries in total. Employment in each ranges from 5 to 1500.

These figures show that the industry is not a large one. There are at least 50 individual corporations in Canada with greater sales or employment.

In any analysis of the industry as a whole, considerable caution needs to be exercised in trying to generalize.

Further detail on the major sectors of the foundry industry can be found in Appendices I, II and III, where ownership, size and production statistics are documented.

TABLE 1. SUMMARY OF FOUNDRY SURVEY RESULTS FOR 1985.

	TYPE OF FOUNDRY				
	Iron	Steel	Aluminum-based	Copper-based	Total
No. of Firms Responding	34	11	8	12	65
Output (1000's tons)	877.5	26.9	9.0	9.2	922.6
Capacity (1000's tons)	1,215.5	45.0	14.9	15.0	1,290.4
% Utilization	72	67	61	61	72
Estimated Sales ($ millions)	1,200	80	80	40	1,400
Employment	7,102	1,134	1,033	665	9,934
Estimated % of Total Industry - Sales Basis	95	65	25	60	79

At least 75% of Canada's foundry industry is in Ontario, although it represents only 0.3% of all employment in the province and only 1.3% of manufacturing employment. From another standpoint, foundries are a part of Ontario's primary metal and machinery industries, but constitute less than 10% of them by employment. Some further comparisons are as follows:

Industry	Ontario Employment
Foundries	13,000
Leather	16,000
Non-Metallic Mineral Production	25,000
Metal Mining	34,000
Primary Metals	70,000
Printing & Publishing	74,000

Source: Unpublished data, Ministry of Treasury and Economics.

In the United States, the foundry industry employed 224,000 in 1985. In Canada, it was estimated that total foundry employment would be about 18,000, or 8% of U.S. employment. The ratio is lower than that for GNP and other measures, since the U.S. foundry industry is relatively larger because of domestic machinery, equipment and defense demand.

MINERAL SUPPLIERS TO THE FOUNDRY INDUSTRY

Personal and telephone interviews were held with the ten major mineral suppliers to the Ontario foundry industry, as summarized in Table 2. All the refractory suppliers and two major sand suppliers are subsidiaries of U.S. firms. For these firms, the foundry industry generally accounted for about 50% of their sales. The two chemical companies, Ashland and Foseco are U.S. and U.K. owned respectively.

There are other small suppliers to the foundry industry who were not contacted. Some of these are quarry operators who supply limestone and dolomite to local foundries. Others are local sales representatives for U.S. firms.

Employment

The ten major suppliers have a total employment of about 500 people in Ontario, half of whom are engaged in manufacturing, processing or packaging.

Technical Service

Most small foundries rely on their suppliers for technical service. The 30 technical service people shown in Table 2 are those people whose job or major responsibility is to provide that service. Most sales people also provide technical service. In many cases this extends beyond the application of their products.

Sales Breakdown

Table 3 shows the breakdown of sales. The total sales of the ten main suppliers are $160 million of which 50% is to the Canadian foundry industry. Approximately $60 million or 75% of minerals or mineral-based sales are made to Ontario foundries. As can be seen in Table 3, the major items are sand, binders and refractories. Only about 40% is manufactured, processed or packaged in Ontario. The balance is simply imported and resold.

TABLE 2. SURVEY OF MINERAL SUPPLIERS TO THE ONTARIO FOUNDRY INDUSTRY.

1. Suppliers		
	Total Number	10
2. Ownership		
	Canadian	3
	Foreign	7
3. Ontario Employment		
		Persons
	Sales	120
	Administration	100
	Manufacturing and Packaging	250
	Technical Service	30
	TOTAL	500
4. Major Ontario Foundry Mineral Supply Firms		
	Asbury Wilkinson Graphite & Foundry Supply Co., Toronto	
	Ashland Chemicals, Mississauga	
	William R. Barnes Co. Ltd., Waterdown	
	Canadian Foundry Supplies Ltd., Toronto	
	C-E Refractories, Welland	
	C&W Refractories Ltd., Hamilton	
	Foseco Canada Inc., Guelph	
	Imtrex Commodities Inc., Oakville	
	Lakeshore Sand Ontario Ltd., Hamilton	
	George F. Pettinos (Canada) Ltd., Hamilton	

TABLE 3. BREAKDOWN OF SALES. RESULTS OF SURVEY OF MINERAL SUPPLIERS.

1. Sales to Ontario Foundries	**millions**
Moulding & Core Sands	$13.0
Natural Binders & Related Additives	7.2
Chemical Binders (including shell resins)	24.5
Refractories (including mould & core washes)	10.2
Fluxes	3.1
Others	2.0
TOTAL	$60.0
Products for resale only	$35.0
Products manufactured or processed in Ontario	$25.0
2. Sales to foundries in other provinces	$20.0
3. Sales to all industries	$160.0

Plant Facilities

Foundry suppliers generally started out as sales representatives or agents. In recent years they have grown faster than the foundry industry by adding facilities for manufacturing, processing and packaging. In some cases Canadian companies have expanded into the U.S. by purchasing foundry supply houses or refractory manufacturers. Ontario companies have also acquired mineral sources in the United States.

Table 4 shows the number and type of facilities operated by 9 of the 10 firms. The tenth firm is a Canadian subsidiary of a U.S. firm that specializes in cupola refractory bricks and blocks. They act as a sales office only.

The current favorable exchange rate was named as a factor in encouraging more local manufacturing or processing.

TABLE 4. PLANT FACILITIES. RESULTS OF SURVEY OF MINERAL SUPPLIERS.

1. Number reporting		10
2. Number with plant facilities		9
3. Equipment		**Number of Companies**
	Resin Coating	5
	Blenders	6
	Screens	4
	Mixers	5
	Packaging Equipment	9
	Grinding Mills	3
	Mullers	3
	Unloading	2
	Storage	10
	Classifiers	3
	Extruders	1 *
4. Total Investment		$40 million

* *refractories*

Mineral Sources

The following data summarizes sources of raw materials for mineral suppliers to the foundry industry:

	Ontario	Other Canadian	U.S.	Other
Moulding & Core Sands			100%	
Natural Binders		5%	95%	
Chemical Binders	25%	25%	50%	
Refractories		15%	80%	5%
Fluxes	90%	5%	5%	

Only about 15% of raw materials are obtained from Ontario sources. These include some of the ingredients for chemical binders, and most of the limestone and dolomite used as fluxes. There are some refractory materials mined in Quebec and a bentonite deposit in Avonlea, Saskatchewan has been developed.

The reasons for the high dependence on U.S. suppliers are:

a. The high capital cost of developing competitive domestic resources.

b. The existence of well-established relationships between local foundry suppliers and the U.S. raw material sources.

c. Half the domestic suppliers are subsidiaries of U.S. firms who own their own mines and/or quarries.

d. Suppliers told us that suitable deposits do not exist in Ontario or are too remote to be competitive.

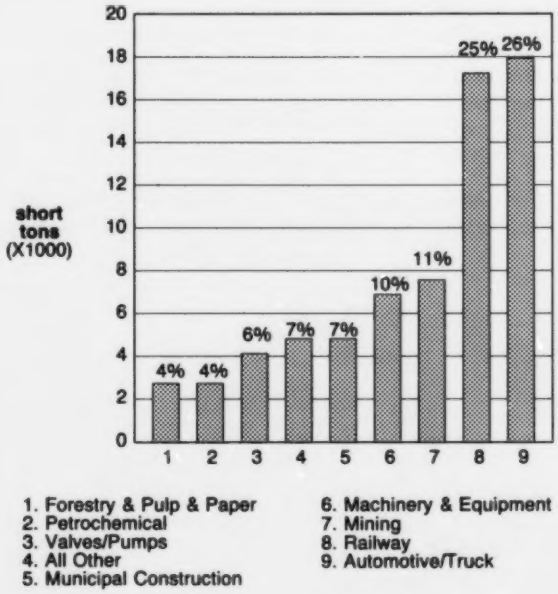
The breakdown by types of sand used in all Ontario foundries is estimated as follows:

Silica Sands		
Ottawa (Illinois) Silica	8%	Estimated 400,000 tons
Wisconsin Silica	1.5%	
Lake Sand	80%	
Bank Sand	8.0%	
Other Silica Sands	2.5%	
Other Sands		
Olivine	5,000 tons	
Zircon	700 tons	
Chromite	2,000 tons	

3. Markets Served by the Foundry Industry

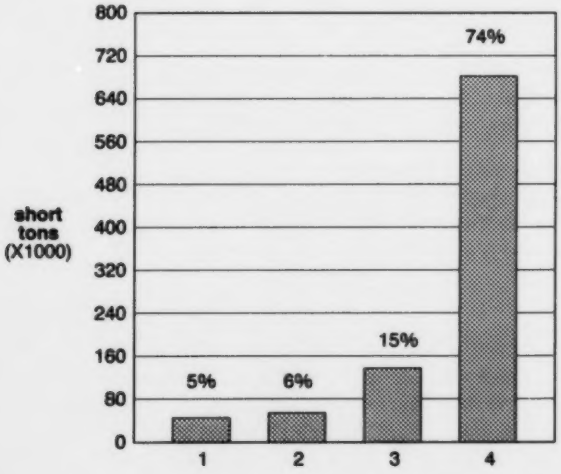
The Ontario foundry industry consists mainly (about 85%) of iron foundries. Grey iron and ductile iron foundries represent almost all of this segment in terms of production. The market served collectively by the foundry industry segments is 2/3 automotive and truck, although automotive and truck represents only 1/4 of the total market for the steel and non-ferrous foundry segments, where no one market segment dominates the industry. This is illustrated in Figures 1 through 5. From the point of view of impact on employment and sales, however, trends in the automotive and truck industry will definitely dominate the health and prospects of the foundry industry as a whole.

FIGURE 2. *Estimated Ontario Steel Foundry Industry Sales By Market Segment (Estimated Tonnage Basis). 1985 Output = 69,000 Short Tons. Estimate Based On Survey Results, And Industry Association Data.*



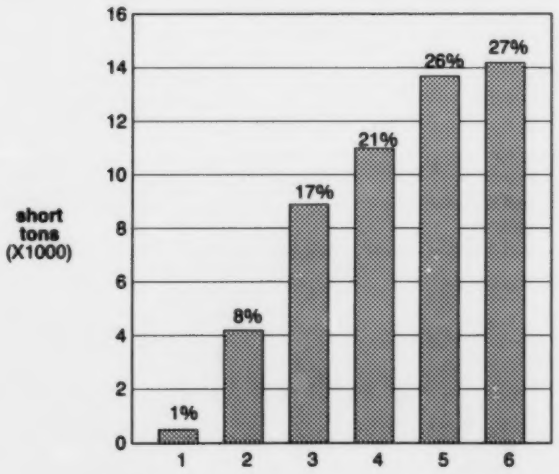
1. Forestry & Pulp & Paper
2. Petrochemical
3. Valves/Pumps
4. All Other
5. Municipal Construction
6. Machinery & Equipment
7. Mining
8. Railway
9. Automotive/Truck

FIGURE 1. *Estimated Ontario Iron Foundry Industry Sales By Market Segment (Estimated Tonnage Basis). 1985 Output = 923,000 Short Tons. Estimate Based On Survey Results.*



1. Machinery and Equipment
2. Municipal Construction
3. All Other
4. Auto/Truck

FIGURE 3. *Estimated Ontario Aluminum Foundry Industry Sales By Market Segment (Estimated Tonnage Basis). 1985 Output = 52,500 Short Tons. Estimate Based On Survey Results, And Industry Association Data.*



1. Plumbing
2. Valves/Pumps
3. Auto/Truck
4. Machinery & Equipment
5. All Other
6. Electrical

FIGURE 4. *Estimated Ontario Copper-based Foundry Industry Sales By Market Segment (Estimated Tonnage Basis). 1985 Output = 52,500 Short Tons. Estimate Based On Survey Results And Industry Association Data.*

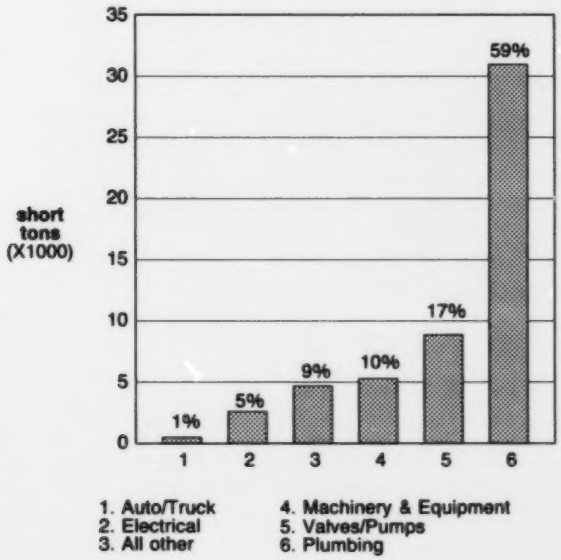
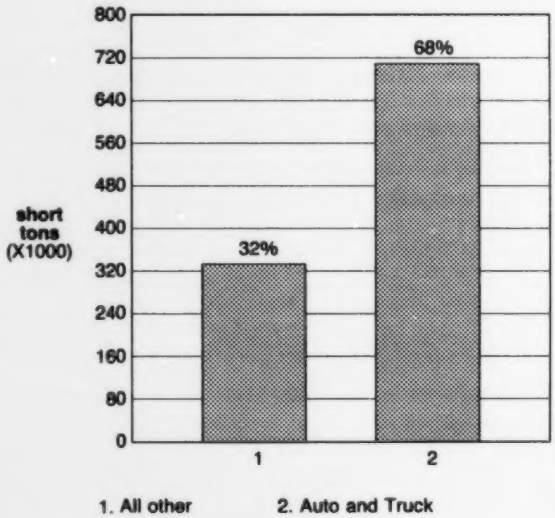


FIGURE 5. *Estimated Total Ontario Foundry Industry Sales By Market Segment (Estimated On A Tonnage Basis). 1985 Output = 1,044,500 Short Tons (Iron, Steel And Non-ferrous Included) Estimate Based On Survey Results And Industry Association Data.*



4. Trends and Outlook for the Foundry Industry

As stated earlier there are basically 3 types of foundries:

a. *Jobbing* – Custom foundry product suppliers.

b. *Proprietary Product* – Characterized by specialized foundry production and other manufacturing operations to produce a finished product, i.e. pipe fittings.

c. *Captive Product* – Specialized foundries producing as an in-house supplier of cast metal components.

There is no easy or practical way to separate the costs of the captive and proprietary product foundry operations from other aspects of these businesses. This is why it is difficult to accurately obtain even basic information such as employment and output. The basic problem is that there is no clear definition of a "foundry".

Due to these problems, as well as the low level of response by firms in certain sectors and the poor standardization of data submitted, the existing statistics from industry associations are extremely poor. It was concluded that little faith could be put in their accuracy.

For the last few years, the only casting statistics have been kept by the Canadian Foundry Association (CFA) and the Canadian Copper and Brass Development Association. These statistics are not available by province and are highly suspect because of the changing numbers of firms reporting each year. For lack of better information, they are included herein, but with qualified commentary.

CANADIAN IRON AND STEEL CASTINGS

Iron casting shipments in Canada are declining as shown in Table 5. This represents a long term decline of about 2% per year in tons shipped. The picture in Ontario is essentially the same, since Ontario represents 80–90% of data reported to CFA.

Canadian steel casting shipments are also declining as shown in Table 6, and decline here is approximately 5% per

TABLE 5. SUMMARY OF CANADIAN SHIPMENTS OF IRON CASTINGS.

	(1000's Short Tons)							
	1979	1980	1981	1982	1983	1984	1985	1986 (est)
Grey	N/A	N/A	535	393	525	630	540	533
Malleable	N/A	N/A	17	10	14	13	11	7
Ductile	N/A	N/A	232	188	231	284	272	319
Alloy	N/A	N/A	40	22	19	26	22	10
Total Iron	1120	802	824	613	789	953	845	869

Source: Canadian Foundry Association Survey.
The CFA could not provide an opinion as to how representative this information was of total Canadian shipments, since it only included survey respondents. It may only represent 60 to 80% of output.

TABLE 6. SUMMARY OF CANADIAN SHIPMENTS OF STEEL CASTINGS.

	(1000's Short Tons)							
	1979	1980	1981	1982	1983	1984	1985	1986 (est)
Carbon	N/A	N/A	128	90	80	101	70	60
Low Alloy	N/A	N/A	17	11	12	4	11	11
High Alloy	N/A	N/A	6	3	2	10	3	5
Abrasion Resistant	N/A	N/A	16	16	12	13	15	15
Total Steel	198	225	167	120	106	128	99	91
Total Iron and Steel	1318	1027	991	733	895	1081	944	691

Source: Canadian Foundry Association.
Data are estimated to represent approximately 75% of total Canadian shipments.

year. Ontario's steel foundries represent only 35–40% of total Canadian output.

U.S. IRON AND STEEL CASTINGS

Table 7 shows U.S. iron and steel casting shipments over the period 1975 to 1986. The long term decline in iron is about 3% per year, while that for steel is about 5% per year. Thus the declines in the U.S. and Canada are about the same.

In a paper delivered to the Foundry Equipment Manufacturers Association in the United States in mid–1986, a Lester B. Knight and Associates consultant described the decline of the U.S. foundry industry over the last 4 decades as having occurred in four stages. He said that in the post–war boom shipments grew dramatically under the influence of booming automotive, machine tool, farm and construction markets. The next stage occurred between 1960 and 1980 which was characterized as one of technological growth. During these years casting shipments continued to grow but considerably more slowly as metallurgical advancements changed the mix of castings produced and allowed them to replace forgings and other fabrications. The decline cycle started in the early 1980's and was predicted to continue through until the end of the century. This decline will take place due to import competition and substitution. While substitution has already begun taking place, Lester B. Knight and Associates believes that there will be a major surge in advanced metals and materials which will make their greatest inroads into castings during the mid to late 1990's and beyond.

CANADIAN NON–FERROUS CASTINGS

Table 8 shows aluminum–based and copper–based casting production reported to the Canadian Copper and Brass Development Association. The copper–based figures are felt to be more accurate since most of the major copper based castings producers report to the association. Copper has been essentially flat except for the substantial down cycle which occurred in the 1982 recession. The bulk of the copper–based castings are sand–cast as opposed to permanent mould or die–cast.

The picture for aluminum–based castings is less clear since the statistics shown represent only a small fraction of the industry and cannot be considered representative. Sources in the primary and secondary metal supply industry indicated that about 75 million pounds of aluminum based castings were produced in Canada in 1985. A very substantial portion of this is in permanent mould castings, but the estimate does not include aluminum die–castings. Ontario represents about two–thirds or more of all Canadian production. Steady growth of about 5% per year has been experienced and it is primarily due to automotive usage.

U.S. NON–FERROUS CASTINGS

Table 9 shows U.S. aluminum–based and copper–based casting shipments in the last 10 years. A further breakout to sand castings is available. Copper–based castings have been declining modestly and the major reason is said to be due to imports of plumbing brass. Copper–based sand castings are declining at a rate of about 5%, or more, per year. This is due to increasing use of permanent mould casting.

The U.S. picture as pertaining to aluminum–based castings is believed to be accurate. It shows that total aluminum–based castings are growing at a rate somewhat in excess of 5% per year, due to the increasing usage in automobiles. The sand–cast portion is declining. Demand for sand castings is primarily for barbecues, electrical and other components. The U.S. Department of Commerce in the publication "U.S. Industrial Outlook 1986" forecasts that "overall domestic demand for non–ferrous castings will continue to be largely determined by trends in motor vehicle production... and technological factors such as the drive to decrease the weight of passenger cars, the substitution of plastics for some cast metal parts and the development of thin wall die–casting techniques. Future prospects for non–ferrous castings will also be influenced by foreign competition.... Shipments of non–ferrous castings are unlikely to increase much more than 1.5% annually to 1990".

INDUSTRY GROWTH

Responding foundries reported the following growth in output from 1980 to 1985:

Iron	+ 30%
Steel	- 48%
Aluminum	+ 44%
Copper	flat

There were difficulties in obtaining complete responses from all companies and in getting accurate estimates for 1980. For the iron foundries the increase comes mostly from half a dozen automotive and other captive/proprietary foundries where it was 44%. All other iron foundries in total were virtually flat, with a substantial range of responses. The decline in steel foundry output was widespread and largely due to weak railway and mining demand. The increase in aluminum output was primarily due to automotive demand. Copper–based demand mostly reflects plumbing brass and was flat.

Forecast growth in the foundry industry for 1985–1990 is summarized below:

Iron	+ 13%
Steel	+ 40%
Aluminum	+ 51%
Copper	+ 56%

TABLE 7. U.S. IRON AND STEEL CASTING SHIPMENTS, 1975 - 1986.

	(thousands of net tons)			
Year	Total Iron	Steel	Total Ferrous	Value of Shipments $1982 (millions)
1986 (est)	9070	840	9910	8976
1985	10490	950	11440	9973
1984	10900	940	11840	10720
1983	9524	729	10253	9063
1982	8499	1017	9516	9641
1981				
1980	12249	1878	14127	14248
1975	13177	1938	15115	15324

Source - U.S. Bureau of the Census

TABLE 8. CANADIAN NON-FERROUS CASTING SHIPMENTS, 1980 - 1985.

	(thousands of pounds)	
Year	Aluminum-based	Copper-based
1985	1209	23492
1984	1438	23500
1983	1108	19835
1982	1697	18087
1981	2101	26355
1980	2072	24952

Source - Canadian Copper and Brass Development Association.
Based on reports from participating companies only.

TABLE 9. U.S. NON-FERROUS CASTING SHIPMENTS, 1974 - 1986.

	(millions of pounds)			
	Aluminum-based		Copper-based	
Year	Sand	Total	Sand	Total
1986 (est)	178	2200	298	460
1985	204.0	2228	328.3	470.0
1984	195.9	2233	367.5	504.0
1983	166.5	1898	328.0	498.3
1982	178.4	1605	339.1	445.7
1981	245.8	1581	414.7	475.6
1980	241.0	1538	434.4	488.7
1979	285.6	2081	542.2	617.2
1978				
1977				
1976	216.6	1845	491.0	549.2
1975	197.3	1375	476.5	514.2
1974	267.8	1759	565.1	665.1

Source - U.S. Bureau of the Census

These forecasts are considered optimistic and stem from a feeling that "things have to get better". They were not well defended when challenged. Some felt the auto boom would continue; others felt that they could substantially increase their penetration of the U.S. market. Most respondents said any forecast would be a pure guess and had to be pressed to give any estimate. It was concluded that little confidence could be placed in these results.

TECHNOLOGY IMPACT

The use of permanent mould and lost foam technologies is expanding into mainly high volume production plants. Such applications are generally found in the foundries serving the automotive and machinery sectors. These technologies, although technically feasible in iron foundries, are making inroads faster into non-ferrous applications in such sub-sectors as plumbing products. With the increasing emphasis on lighter vehicles, another shift is taking place within the foundry industry from ferrous to non-ferrous automotive castings. This is precisely where permanent mould and lost foam technology use is growing the fastest.

Since use of these technologies reduces the demand for sand by up to 90%, it is starting to cause a significant downward trend with respect to the demand for sand per ton of cast product.

It was concluded that nothing would stop this trend. Many existing mineral suppliers are already being forced to look at new foreign markets just to maintain their existing sales volumes.

The current trend in the foundry industry is towards more use of capital (and better technology) with the objective of reducing both material and labour costs. Therefore, the only opportunity for new materials is in situations where material cost could actually be reduced by use of a more cost-effective and/or more efficient material. This would likely be an improvement to existing materials that enhance overall productivity or product quality.

OTHER FOUNDRY TRENDS

The number of foundries has declined in all sectors. Smaller foundries have not been able to survive down cycles and price competition from modernized foundries or imports. Industry consolidation and rationalization is expected to continue.

Automotive demand has increased while demand from many other markets has decreased. The automotive industry now represents at least two-thirds of casting demand for Ontario foundries. The great majority of automotive shipments go to the U.S.

Exports to the U.S. appear to be increasing in many product markets. This is due to the exchange rate and U.S. foundry closures.

Profitability in the industry is mixed but is trending downwards. Casting prices were static in the early 1980's and increased very modestly in the last couple of years. However, costs are rising. Not only have lower profit margins resulted but also investment has declined. This is not true of the larger automotive foundries which show average profitability and which have invested in more productive facilities.

DETAILED SURVEY RESULTS

Detailed survey results for each major industry sector are provided in Appendices I - III.

5. Implications for Raw Material Supply

MAJOR INDUSTRIAL MINERAL PROPERTIES AND APPLICATIONS

The characteristics of representative commercial grades of foundry sands are shown in Table 10.

Mould And Core Sands

Lake Sand

Typical analyses are SiO_2 96.70%. This material is suitable and widely used for cast irons and non-ferrous castings. The material must be washed, dried and screened. It must be consistent in chemistry and be free of fractured or compound grains. It must also be available in a variety of screen size distributions and these distributions must be consistent from shipment to shipment.

Ottawa Silica Or Equivalent

Typical analyses are SiO_2 99.7% and the sand is round grained. This material is used for steel castings which requires a mould material with a high fusion point. Customer specifications for grain shape and size distribution are generally much more rigid than for lake sands.

Other Silica Sands

Some silica sand is brought into Ontario from New Jersey and Wisconsin deposits. Their quality is almost equal to Ottawa silica sand but their use is dictated by transport costs to the foundry.

TABLE 10. COMPARISON OF FOUNDRY BASE SANDS*.

	Lake Sand	Ottawa Silica Sand	Olivine Sand	Chromite Sand	Zircon Sand
Colour	light brown	white	greenish-grey	black	white/brown
Moh's Hardness	6.5-7.0	7.0	6.5-7.0	5.5-7.0	7.0-7.5
Dry Bulk Density (lb/cu ft)	90-100	90-100	105-115	155-165	170-180
Specific Gravity	2.6-2.7	2.6-2.7	3.2-3.4	4.3-4.5	4.5-4.7
Grain Shape	round/angular	round	angular	angular	round
Thermal Expansion (% in/in)	0.018	0.018	0.0083	0.005	0.003
Apparent Heat Transfer	average	average	low	very high	high
Fusion Point	1427-1760°C (2600-3200°F)	1427-1760°C (2600-3200°F)	1538-1760°C (2800-3200°F)	1760-1982°C (3200-3600°F)	2038-2204°C (3700-4000°F)
High Temperature Reaction	acid	acid	basic	basic	acid
Wettability with Molten Metal	easily	easily	not generally	resistant	resistant
Chemical Reaction	acid-neutral	acid-neutral	basic	neutral-basic	acid-neutral
AFS Grain Fineness Number Ranges	48-55	10-128	10-200	50-90	95-160
Acid Demand Values					
4.0 pH	6-46	1-4	10-18	3-5	<1-1
7.0 pH	3-38	<1-3	9-17	2-4	<1-1
Chemical composition (wt %)					
SiO_2	96-99	99.6-99.9	39-42	<1.5	na
Fe_2O_3	<0.5	0.010-0.070	6-8(FeO)	~25(FeO)	<0.05
Al_2O_3	<1.0	0.050-0.100	0.2-0.8	14-16	<2.00
CaO	<0.5	0.010-0.020	na	<0.5	na
MgO	<0.5	0.002-0.010	45-99	9-10	na
K_2O	<1.0	0.003-0.030	na	na	na
Na_2O	<0.5	0.007-0.010	na	na	na
TiO_2	<0.1	0.010-0.020	na	na	<0.35
Cr_2O_3	na	0.001-0.002	0.6-0.8	>45	na
ZrO_2	na	na	na	na	>65
LOI	<0.3	0.100-0.200	na	na	<0.10

na - not available

Note: The above chemical compositions are representative of a range of commercially available products but are not to be considered all inclusive.

** modified from a brochure on olivine by the Applied Industrial Minerals Corporation, Deerfield, Illinois.*

There is some minor consumption of bank sand (Juniata) and natural sand (Albany). However, these are not significant amounts and are rapidly disappearing.

Olivine

Crushed olivine is used for moulds in manganese steel foundries where silica is not compatible with the metal. It is also used by some non-ferrous foundries because of its thermal properties, durability and low silicosis hazards. Grain size control considerations are the same as any other sand.

Typical analyses are:

a. Chemical
MgO - 45% to 49%
SiO_2 - 39% to 43%
Fe_2O_3 - 6% to 8%

b. Mineralogical
Olivine - 92% to 93%
Enstatite - 5%
Serpentines - 1% to 2%
Chromite - 1%

Note: Olivine is a solid solution of 2 minerals - forsterite and fayalite. Foundry grades require that at least 90% of the olivine is made up of forsterite.

Special Sands

Zircon and chromite sands are used in very small amounts - usually only in a small section of a mould or core where special refractory and thermal properties are required.

Zircon sand is zirconium silicate and typically contains at least 67% ZrO_2. A chromite sand is essentially a spinel; foundry grades contain 35% to 50% Cr_2O_3.

Binders

Sand binders are of two types, clay or chemical. All clay binders used in Ontario are brought in from U.S. bentonite deposits. Southern bentonite comes mainly from South Carolina and western bentonite from Wyoming. There is only one commercial deposit in Canada, in Saskatchewan, but virtually none is used in Ontario because of its higher cost.

Chemical binders are based on phenolic urethane, furan, epoxy/ester or sodium silicate. There are many proprietary variations of these chemicals and the catalysts used with them. Many chemical binders are manufactured in the U.S. and imported into Canada.

Carbonaceous Mould Additives

These include finely ground coal (seacoal), pitch, coal tar, gilsonite (a type of graphite) and proprietary oils.

Carbonaceous Materials For Moulding And Chemical Control

The most common materials in use are:

Calcined petroleum coke,
Calcined low-ash, low-sulphur coal,
Synthetic graphite.

These are usually proprietary products for which official specifications do not exist. Users usually specify maximum levels of fixed carbon. A very common requirement is a maximum of 0.2% sulphur and a minimum fixed carbon of 95%.

Each foundry makes an economic decision based on the prices of the various grades and the extra operating costs involved in the use of the lower grades.

Natural graphite is not suitable for most foundry applications. It does not dissolve easily in molten iron or steel and because of its high surface area, flakes tend to float on the surface of molten metal.

Fluxes

Limestone

This material is used in iron and steel foundries for desulphurization. Size specifications will depend on the application. The major chemical requirement is that the silica content should be less than 2%.

Dolomite

This material is used for the same purpose as limestone where its special properties are required. Dolomite calcines more readily and slag melting points are lowered. The same 2% maximum SiO_2 is required.

Fluorspar

Use of this material is declining very rapidly due to its effect on emission control facilities and health hazards.

Other Fluxes

Other minerals and chemicals are used as secondary fluxes, usually in proprietary blends in the form of briquettes. Common materials are:

Sodium carbonate,
Calcium carbide,
Alumina,
Calcium and Sodium Borates,
Olivine,
Ilmenite.

Refractories – Melting, Pouring, Cores And Moulds

Almost all of the materials used in the foundry industry are proprietary compounds supplied in many different forms. As noted elsewhere in this report, Canadian manufacturers obtain most of their raw materials in the U.S. and Europe. However, there is recent competitive pressure to develop domestic sources.

FOUNDRY MINERAL CONSUMPTION

Table 11 provides the results of an annual survey of foundries by Energy, Mines and Resources Canada (EMR). Approximately 200 foundries were surveyed in each of the three years from 1983 to 1985. Both ferrous and non-ferrous foundries are included in this survey. Comparable statistics prior to 1983 are not available, since survey methods changed that year. In prior years the survey had embraced all manufacturing, not just foundries.

For silica sand, the tonnages reported are all imports. Foundries represent about half of all imports. Other applications include glass manufacturing, silex and firebrick.

Domestic production of silica is much larger than imports, and goes entirely to non-foundry applications, mostly glass and insulation manufacture. A 1982 study of foundry moulding and core sands by Robert Shnay and Associates provided the following data for consumption of silica sand by Canadian foundries for 1977 to 1982:

Year	metric tonnes
1982	420 750
1981	519 750
1980	542 347
1979	800 514
1978	653 175
1977	607 437

Source: Robert Shnay and Associates (1982)

While it has not been possible to affirm the comparability of these statistics, it is evident that silica consumption has been declining. Note that the 1985 EMR total has been revised downwards by 100 000 tonnes, due to a confirmed error in the government survey data. It is also believed that the chromite sand data is far too high.

Table 12 provides the results of a special analysis by EMR to break down 1985 survey responses by Ontario foundries only.

TABLE 11. CANADIAN CONSUMPTION OF MINERALS BY FERROUS AND NON-FERROUS FOUNDRIES.

	metric tonnes		
Sands	**1985**	**1984**	**1983**
Silica Sand	419 787	539 651	367 053
Chromite	82 631	88 851	81 206
Olivine	10 692	10 598	9 785
Silica lump	10 187	8 113	9 020
Silica flour	882	3 925	3 908
Zircon	1 793	10 346	1 280
Clays			
Bentonite	53 869	56 115	44 762
Fire Clay	6 142	6 338	4 867
Ball Clay	28	138	0
Other Clay	901	639	1 213
Kaolin	135	111	263
Other			
Limestone	54 115	59 258	46 734
Lime	1 948	2 253	2 445
Fluorspar	4 964	5 464	6 216
Graphite	4 904	4 857	3 991
Riser Sleeves	160	170	126
Slag Coagulants	1 232	1 082	637

Annual Survey - Energy, Mines and Resources, Canada

TABLE 12. CONSUMPTION OF MINERALS BY ONTARIO IRON FOUNDRIES 1985.

	(metric tonnes)
Sands	**1985**
Silica Sand	354 335
Chromite	77 200
Olivine	720
Silica lump	5 360
Silica flour	N/A
Zircon	902
Clays	
Bentonite	54 020
Fire Clay	4 940
Ball Clay	N/A
Other Clay	850
Kaolin	N/A
Other	
Limestone	50 965
Lime	N/A
Fluorspar	N/A
Alumina	378
Iron Oxide	842
Silicon Carbide	1 135
Graphite	4 220
Coal	365
Coke	110 275

Annual Survey - Energy, Mines & Resources, Canada

MINERAL SUPPLIER FORECASTS TO 1990

The suppliers also predict that total sales to Ontario foundries will grow by about 5% from 1986 to 1990 for an average of 1% per year. However, they do not expect growth in mineral product consumption. Factors reported to be affecting mineral consumption are:

a. Moulding & Core Sands
—Increasing reclamation
—Lower sand to metal ratios
—Higher yield
—Lower scrap

b. All Binders - possible growth of chemical at the expense of natural, but overall no growth situation as in sands.

c. Refractories - trend to more sophisticated products with higher price but longer life.

d. Fluxes - there may be some growth as a result of demands for higher quality.

e. Rationalization of the industry and the resulting mergers and acquisitions.

f. Increased value added by manufacturing and processing and more sales of higher value-added products.

g. More sophisticated refractories and binders which will either last longer or require less material.

h. The dollar value of foundry sales may increase in part by the market demand for lighter, stronger and more reliable castings, or by the move towards more sophisticated materials such as austenitic ductile iron. However, this trend will result in lower consumption of the mineral-based materials per ton of product.

The automotive industry has frozen the prices it will pay for castings. This in turn has put great pressure on mineral suppliers to hold their prices down for the next two or three years.

PROFITABILITY

The mineral supply industry, faced with a relatively static market, is very competitive for market share. It was difficult to obtain data on profits. However, several firms were willing to disclose what they considered to be typical gross margins for various groups of products. Their estimates were quite consistent and the following data represents their responses.

☐ Average Gross Margins	20 to 25%
☐ Average Net Margins (before tax)	6 to 8%
☐ Average Gross Margins by Product	
Resale only	5 to 10%
Packaged and bagged bulk materials	15 to 25%
Manufactured and processed products	25 to 30%

As one might expect, the typical margins increase with the value added by the supplier. In some cases proprietary products claiming superior quality may have higher margins. However, the increasing sophistication of foundry purchasing staff, requirements of process control procedures and labelling requirements for health and safety have led to an erosion of the dominant positions once held by many proprietary products. The higher prices and margins are less acceptable and lower-priced competitive products are replacing them.

MINERAL USAGE TRENDS

Foundry moulding and core-making sand usage patterns are not changing significantly. For some time, foundries have been changing over to chemically-bonded sands and this is continuing, although more slowly as potential applications become fewer in number. Sand usage per ton of good casting output is dropping slowly as more sand reclamation equipment is installed. Also, more efficient sand and moulding systems are being installed. Some foundries are increasing output in permanent mould processes. The auto foundries are experimenting with new non-sand processes such as lost-foam moulding. Premixing of sand and binders seems to be growing modestly.

It was not possible to identify any changes in refractory material or flux usage, except a general trend to more judicious usage to lower material costs or to take advantage of better products being made available. Very little information was provided by foundry respondents since purchases of refractory and flux materials are extremely small in relation to other costs.

Very few foundries indicated any interest in central sand reclamation. Major objections raised were shipping costs to and from a central plant, and technical problems concerning the ability to deal with all types of dirty sand.

OPPORTUNITIES FOR DOMESTIC SUPPLIERS

As stated elsewhere in this report, the foundry industry in general is currently undergoing a rationalization process. At the same time there has been a continuing decline in the production of metal castings. Foundries have had to be much more rigorous in their material management — both in reducing consumption and also in negotiating optimum combinations of quality and cost.

It is not surprising that foundry supply houses are also going through a period of rationalization and retrenchment. Competition in all materials is very sharp and prices have shown little, if any, increase since 1981. Suppliers are not much more amenable to supplying a foundry's special needs and they also welcome smaller orders. In the case of refractories and fluxes, more sophisticated products are now available — again with little or no increase in price.

The current imbalance between supply and demand is not likely to be corrected by increased demand. New entrants in the

foundry supply business only become established at the expense of existing participants.

Silica Sands

Sand cost is a small percentage of overall casting costs and it has been declining over the years as moulding and sand systems have been improved. These economic constraints have been exacerbated by the sharp and continuing decline in casting output, and the increasing competition among suppliers. Any new entrant would not only have to be competitive in price, but would also have to have the extensive facilities required for ensuring the quality of their product. Furthermore, in order to provide a broad range of screen sizes, a sand supplier must have a widely diversified market to take up all his material.

Ontario foundry consumption of silica sand decreased from about 550,000 tons in 1981 to 347,000 tons in 1982 and came back up to about 400,000 tons in 1986 (Shnay and Associates 1982).

Another consideration is the relative cost of sand. A generous rule-of-thumb is that iron, steel and copper alloy foundries use about 1,000 pounds of new sand per ton of finished product. In the case of an iron foundry the direct cost of sand would be about 1.25% of the finished product. This percentage would be much lower for other foundries.

Under those conditions, there is little incentive to experiment with a new sand. Why risk an expensive casting to save pennies on the sand?

There would clearly have to be a very unusual set of circumstances that could justify a new entry in the silica sand business and such conditions cannot be forseen at the present time.

Non-silica Sands

Most of the olivine, zircon and chromite sands are used by steel foundries. The sand consumption by all Ontario foundries was 3,000 tons in 1982 and has been estimated at 7,700 tons for 1986. This represents a sharp rise in 5 years and was predicted in the Shnay study (Shnay and Associates 1982). This rise is an example of how foundries are becoming more sophisticated in their use of materials.

Zircon sands are imported from Australia and South Africa. Most chromite sands come from Europe and South Africa. The olivine sand used in Canada comes from the southern U.S. and Washington State. There have been quality problems in the fine grain sizes.

All of these special sands are expensive and have to meet rigid requirements. There could be opportunities for Ontario sources. To penetrate the whole North American market, however, each case would have to be studied separately to establish grade, reserves, cost of production and potential return. The Ontario market alone will not justify any such development.

Binders

Small changes in chemistry and/or grind can have very significant effects on mould properties. In an average iron foundry the cost of bentonite would be about 0.07% of the direct cost of the finished casting. This again would be even less for other types of foundries. Under these conditions, a foundry is not likely to risk their production in order to gain a tiny saving.

Since there is already an oversupply situation, there would not be much opportunity for an Ontario supplier.

Western bentonite is mined and processed in Avonlea, Saskatchewan, and has been able to compete in western Canada against material from Wyoming.

Fluxes

Ontario quarries now supply all the foundry needs for limestone and dolomite. Any growth in this area would require growth in the foundry industry.

Other Materials

For the most part all other materials are proprietary blends and mixtures. Some fluxes, washes and refractories are produced in Ontario using domestically sourced materials. Since the composition of these items are considered proprietary, one cannot determine the amounts and kinds of raw materials that are used.

Material Costs

Typical material costs are shown in Table 13. The variables that influence pricing of these materials are specifications of order, size of order and, most importantly, the transportation cost. The distribution of a particular material also determines its price and at present there is some retrenchment and changes are taking place in the distribution network. All these factors make it impossible to provide accurate representative pricing for materials. The price is usually the result of negotiation and specific volume supply contracts between each supplier and foundry, for products with varying specifications. The information in this report is as detailed as can be provided on a generalized basis.

It is expected there will be continuing pressure on suppliers to hold current prices level and at the same time improve quality and reliability of supply. There is not expected to be much, if any, increase in the cost of sands, unless it is due to rises in transportation costs.

The main advantage of purchasing large volumes of materials (such as sand and refractory materials) is not in taking advantage of supplier price breaks but rather in the economies of transportation. Freight can comprise 5 to 70% of the cost of delivered raw materials. For example, one foundry currently pay-

ing $65 to $70 per ton for sand could cut its cost to $40 per ton if it could buy by the carload and bring it directly to the plant. Another foundry paying $25 per ton for sand could reduce its costs by $10 per ton in the same way. As a further example, another foundry buying sand in bags at $30 to $35 per ton could reduce its costs by $10 to $12 per ton by buying truckload quantities.

For various reasons, it is not appropriate for these particular companies to purchase materials in quantities larger than their current practice. However, perhaps there are joint buying arrangements that could be established with other foundries (even competitors) that would reduce transportation costs. This opportunity does not appear to have been explored significantly by foundry operators.

TABLE 13. TYPICAL MATERIAL COSTS.

Type of Sand	Source	Price at Source	Destination	Transport Cost
Ottawa Silica	Ottawa, Illinois	$15/ton	Hamilton	$36/ton
Lake Sand	Hamilton plant	$22/ton	Windsor	$11/ton
Ottawa Silica	Hamilton warehouse	$52/ton	Cambridge	$7/ton
Zircon*	Mine	$200/ton	Rail Delivery to Hamilton	
Chromite*	Mine	$217/ton	Rail Delivery to Hamilton	
Olivine*	Hamilton warehouse	$285/ton		
Binders				
Bentonite - $225/ton F.O.B. Hamilton				
Phenolic Urethane - $1.25/lb				
Isocure - $1.05/lb				
Furan - $1.00/lb				
Phenolic Ester - $ .90/lb				
Phenolic Resin (Shell) - $ .98/lb				

** Zircon and chromite prices are for large shipments direct to a foundry in Hamilton. Small users would pay considerably more. Olivine price is for a 10-ton lot from a Hamilton warehouse.*

6. Sand Reclamation

Sand reclamation offers a foundry the opportunity to conserve material and to also reduce the solid waste load that requires disposal. In some cases the waste material is potentially toxic and must be removed to special disposal sites.

TYPES OF SYSTEMS

There are three basic types of reclamation systems:

a. *Mechanical attrition* is mainly used for organic binder systems such as phenolic urethanes, furans, and epoxies. Under suitable conditions these systems can reclaim up to 80% of the used sand to a state that it can be used as new material.

b. *Thermal reclamation* is used in the final step after mechanical attrition or as the sole process for shell (phenolic resin) sands. Over 85% recovery can be attained.

c. *Wet or chemical reclamation* systems are used for reclaiming sands bonded with clay, sodium silicate or other inorganic binders. These systems generally incorporate a preliminary mechanical attrition stage.

RECLAMATION PROBLEMS

The most pressing problem for Canadian foundries is to recover organically-bonded air-set sands. The two most common systems are phenolic urethanes and furans. These represent the greatest disposal problem.

Many foundries have installed mechanical attrition systems. Very few are achieving even 80% recovery. This is in part due to the design of the equipment, poor maintenance or improper operation. However, the major cause is that the foundries use far more sand per ton of metal than mechanical attrition can handle. The proportion of sand that has not been affected by the heat of the casting process is far larger than anticipated by the machine designers.

NEW TECHNOLOGY

Thermal reclamation can resolve these problems. Until recently this step was only feasible for very large foundries. A high capital investment, coupled with high energy, maintenance and other operating costs made it uneconomical for most companies.

A new type of thermal reclamation system has been developed in England, and is now being manufactured by Quipteck Inc. in Brampton, Ontario. This unit is electrically fired and is available in small sizes. The capital and operating costs are much less than the traditional oil or gas fired units. The first of these units is now being installed at Magalloy Foundry in Stratford and the subject is under serious investigation by at least two other Ontario foundries.

Ontario Hydro has also studied the Quipteck method of thermal reclamation.

FEASIBILITY STUDY

The feasibility of centralized reclamation service should be studied. The following operations should be included:

a. *Thermal reclamation* of organically-bonded sand as a final step for foundries with mechanical systems. The 20% or more of system sand would be shipped to the reclaimer instead of to a safe disposal site. This unit would also reclaim shell sand and core butts.

b. *Mechanical attrition* equipment as a preliminary step for all sands.

c. *Wet systems* to serve as the final step for inorganically bonded sands.

An operation such as this could reclaim at least 75% of the waste sand now generated by the foundries.

A feasibility study would have to address technological as well as economic aspects. The major steps in this feasibility study would be as follows:

1. Evaluate existing technology

This would involve a study of various users of recovery systems in order to evaluate their real success and to relate their performance to various technologies. Discussions with systems suppliers and reliance on their performance specifications is not sufficient. There are at least 4 reclamation system users in Ontario at present.

2. Examine new technologies

Several new reclamation technologies have been developed in Ontario but may not have been adequately tested for performance.

3. Identify the best options in reclamation technology

The study would have to determine the development and facility costs for each technology option. The key output of this and the two previous tasks is a reliable estimate of the percent recovery.

4. Synthesize operation alternatives to study the financial feasibility

In this step, potential facility locations would be identified. Operating plans and projected costs would be compiled. Important factors to be considered would be the inbound and outbound freight costs as well as the fixed costs of supporting the investment and administration of the venture.

SAND RECLAMATION ECONOMICS

This section deals with organically-bonded sands only. It provides 2 case examples, one for an individual foundry and one for a central operation.

Case 1 — Individual Foundry in the Cambridge Area

Sand usage: 1,000 tons per year.
Price: $22/ton and $8.00 transport.

a.	*No Reclamation*		
	Costs – Sand	$30,000	
	– Disposal	10,000	
	Total		40,000
b.	*Mechanical Reclamation*		
	Costs – Sand	20% replacement	$6,000
	– Disposal	200 tons @ $10	2,000
	– Operating Cost @ $5/ton		5,000
	Total		$13,000
	Annual saving		$27,000
			or $27/ton
	Estimated Capital Cost		$150,000
	Pay back period		5.6 years
c.	*Mechanical and Thermal*		
	Costs – Sand 5% replacement		$1,500
	– Disposal		500
	– Operating		7,000
	Total		$9,000
	Savings		$31,000
			or $31/ton
	Estimated Capital Cost		$270,000
	Payback		8.7 years

NOTE: Thermal reclamation will improve quality. For equivalent quality with the mechanical unit alone, one would probably have to replace 50% of the sand with new material for each cycle. This would decrease the savings to $15,000 per year and increase the payback period to 10 years.

Case 2 — Central Unit in the Cambridge Area

Sand usage: 10,000 tons per year.
Operating: 24 hours/day, 5 days/week.

a.	*No Reclamation*		
	Costs – Sand	$300,000	
	– Disposal	100,000	
	Total		$400,000
b.	*Mechanical Reclamation*		
	Costs – Sand		$ 60,000
	– Disposal		20,000
	– Operating Costs at $3/ton		30,000
	– Transportation		90,000
	Total		$200,000
	Savings		$200,000
			or $20/ton
	Capital Investment		$250,000

Assume the operator charges $10/ton to cover sales, administration and depreciation. The total savings to the foundries would still be $100,000 or $10/ton of sand.

c.	*Mechanical & Thermal Reclamation*	
	Costs	$15,000
	Disposal	5,000
	Operating Costs	50,000
	Transportation	97,500
	Total	$167,500
	Savings	$233,500
		or $23.35/ton
	Capital Investment	$400,000

If the operator charges $15/ton to cover sales and administration depreciation, total savings will equal $82,500 or $8.25/ton.

LITERATURE SEARCH

There are many articles in foundry journals on sand reclamation. Selected references are provided in Appendix VI as a guideline to reclamation issues, supplies, technology and economics.

7. Conclusions

FOUNDRY DECLINE

The key issue facing the foundry industry is obsolescence. The industry is mature and declining. While it is risky to generalize about so diverse and fragmented an industry, demand for castings in most market segments has changed in the past 10 to 15 years. A number of factors are at play:

- Design changes in end products and their components;
- Material substitutions;
- Casting technology changes;
- World trade and import competition.

Design Changes

Automobiles are smaller and lighter than they were in the early 1970's. The number and weight of metal castings in cars and trucks is lower because of design changes. Examples of this are:

- Disc brakes replacing drum;
- Smaller engines;
- Integral chassis and body designs, i.e. fewer components.

The same types of design changes have occurred in farm, mining, construction and virtually all types of machinery or equipment.

Material Substitutions

The automobile is, again, the best example of a market where cast metal is being replaced by other materials. Plastic components are continuing to be substituted for metal, including cast metal. Fabrications are also replacing castings.

Inroads made by plastic in other casting applications such as water and soil pipe, plumbing and fittings, is almost complete. As improved plastics are developed, other applications such as valves and pumps, equipment components, will convert to plastic. Ceramics will likely replace other types of castings which depend on heat-resistant characteristics such as engine components, turbine blades, etc.

Casting Technology Changes

The major factor here is metallurgy. Higher strength metals developed in the last 20 years have led to lighter castings. Thus casting tonnage output is lower. Ductile iron and various alloy steel castings are the most common examples.

Another weight-reducing factor is the trend to thinner wall castings made possible by improved moulding and coring processes, as well as better metallurgy.

Import Competition

Perhaps the biggest factor of all is the development of manufacturing capability in countries with lower labour rates than the U.S. or Canada. Japanese industries, including its foundries, have exported large numbers of automobiles, construction equipment and other products which have a substantial casting content and generate aftermarket demand for cast parts. Japanese and other Asian foundries have had an advantage in these markets.

World trade growth, low labour rates and favorable governmental policies have also encouraged other types of casting imports from Third World countries. In the past few years imports of plumbing brass, municipal/street castings and wear parts, among others, has increased substantially.

Taking all of these factors together, it must be concluded that the Ontario foundry industry will decline over the next 5 years, except in the aluminum segment where it will probably continue to grow modestly. Declines of 3% per year will likely be experienced in iron and copper-based castings, while a decline of 5% per year will be experienced in steel castings. These are estimates and represent the expected continuation of historical trends over the past ten years.

IMPLICATIONS FOR THE INDUSTRY

The foundry industry faces the problems of most mature industries. Prices are depressed. They have increased in the last five years by only 5 to 10% in most product lines. This is well under the compounded inflation rate. There is intense competition from all directions — between domestic competitors, with foreign competitors and against substitution materials or products. Profits are below average, and with certain exceptions, investment levels are very low. A number of foundries have gone out of business in Ontario over the last 5 years and more can be expected to go out of business in the future. It is estimated that at least 30 Ontario foundries have gone out of business in the last 10 years. Most have been small foundries and captive operations.

The industry is cyclical as a result of cycles in primary demand for machinery and equipment, automobile and railway car purchases and construction spending. This cyclical pattern and inability to control market demand reinforces mature industry characteristics in prices, competition and profitability.

Another major weakness of the industry is in its manpower resources and management. The foundry is not an attractive place to work. This is especially the case when foundry jobs are compared with growing service industry and high-tech jobs. Foundries are noisy, dusty and dirty places to work. They usually do not attract the best local labour. Often compensation lev-

els are lower than in other industries. In addition, foundry employees are often older than average, management has come up through the ranks and has received relatively little professional management education compared to other sectors.

In this environment, one could not expect foundry operators to be venturesome innovators and entrepreneurs. In fact, the industry is known for its conservatism and slowness to accept change. This is not entirely attitudinal. Metal casting is still in many ways an art and not a science. Productivity and quality control result as much from experience and judgement on the shop floor, as from managerial systems, controls and management science techniques. Thus foundry industry management tends to be conservative and production-oriented.

FOUNDRY SUCCESS FACTORS

Success in the jobbing foundry industry has traditionally required a high degree of management skill in:

- market selection — selecting profitable casting markets in which to compete.
- market-investment match — ensuring that foundry equipment and technology provide competitive advantage in the chosen market.
- customer service — a full understanding of the customer's business which allows superior service, from application engineering through to product delivery.

In other words, to be successful in a jobbing foundry, management needs to be market-oriented, knowledgeable and venturesome in capital spending, and to provide the best service to customers.

With the sharp decline since the late 1970's of many of the industries which foundries supply, these factors have become even more important. A steel foundry, such as Dofasco, cannot survive if it continues to target the Canadian railway casting market when that market has declined to half of its former level and has little prospect for recovering. On the other hand, an iron foundry which chose to specialize in high quality automotive components, has won and done well in the 1980's.

What is evident in our analysis of Ontario foundries is that a North American and even a world view of foundry competition success factors is necessary to do well in this mature and declining industry. World-class entrepreneurs are needed in our foundry industry. There is intense competition with foreign foundries for survival. To compete successfully there is a need to understand U.S. and world casting markets and invest in the most advanced technology. Ontario's foundry industry must rationalize and consolidate.

MARKET OPPORTUNITIES

The automotive casting market has generated the only significant growth in Ontario's foundry industry. Free trade resulting from the 1965 Auto Pact and favorable exchange rates have created opportunities, of which Ontario iron and aluminum foundries have taken advantage. In 1975, Ontario iron foundries shipped 440,000 tons of auto castings, while in 1985 they shipped at least 675,000 tons. This increase offset other iron casting market declines which averaged more than 50%. Over 75% of Ontario's automotive castings were produced by the "Big Three" automotive captive foundries. Another 10–15% was produced by U.S. subsidiaries of large auto parts companies. The remaining 10–15% was produced by a handful of Canadian owned foundries. These companies did follow success strategies by consciously focussing on the auto parts market and by investing heavily to be able to compete with U.S. foundries. They have successfully penetrated the U.S. market and ship over 80% of their output there.

The future is difficult to predict. The possible effects of the recent Canada – U.S. free trade agreement are not easy to forecast. Existing exports could be threatened and the exchange advantage may be reduced. Ontario's auto part foundries are themselves in doubt about future growth. A few believe it can grow, but most forecast flat or 2–3% per year growth. It is believed that new automobile demand has peaked and will fall or at best remain flat for the next few years. Canadian foundries will not likely continue to increase their share of the U.S. market, as they have in the past five years. This means limited investment in new foundry equipment can be expected, and an overall "stand pat" attitude by automotive foundries. In addition to declining demand for castings by this sector, the continued declining share of the market held by U.S. auto makers will have an even more severe impact on casting demand.

The rest of the casting market available to Ontario foundries is extremely diverse. The larger segments, all of which are far less than 10% of automotive casting's tonnage, include the following:

Railway
Municipal/construction
All Machinery and Equipment Components
Plumbing Brass
Electrical Components

All of these segments in 1985 were about 50% of their 1975 tonnage. Some of this decline was due to imports, but most of it was due to reduced primary demand and to substitution or design change.

Opportunities are few. The major efforts to rebuild lost volume are directed at the U.S. market. Where economic re-adjustments in the 1980's have caused foundries, especially captive ones, to close down, there are often opportunities for Canadian foundries. They usually cannot compete in high volume

castings, such as railway, even with the favourable exchange rate. However, with proximity, quality and good sales efforts, they can break into U.S. markets where competing foundries are weak. They have done so to the point that American foundrymen are demanding more protection.

There are opportunities to take business from other foundries through exports as well as improved metallurgy or efficiency. These do not seem to be opportunities of any significance to replace other materials or generate major new casting applications.

FOUNDRY MINERAL SUPPLY

Mineral usage by the foundry industry is declining. This is due to casting output decline, to greater use of sand reclamation and permanent mould and other non-sand moulding processes, a continuing trend to chemical binders instead of clay and generally to the more economic use of materials.

The 1985 Ontario foundry market for industrial minerals was only about $35 million (excluding chemical binders). Over 90% of these minerals come from the U.S. The unique properties of these imported minerals, their relatively insignificant cost and the risk of change, has created a strong reluctance to change mineral usage practices in the foundry industry.

As a consequence, significant opportunities for Ontario mineral suppliers in the foundry market have not been identified. Most suppliers are diversifying away from foundry market dependency. In fact, they have already reduced to 50%, on average, the proportion of their total sales to foundries.

It is, nonetheless, difficult to generalize about foundry minerals. There are at least 30 different minerals used by foundries, each of which has unique properties and applications. Most of these minerals are used in very small quantities. Indeed, the cost of all minerals to a typical foundry is less than 3% of casting sales. Purchase decisions for most items are made at lower management or shop floor levels. Given the conservative attitudes of foundrymen, and with limited savings potential, there is little desire to risk change. There are few changing trends in foundry mineral usage.

Similar factors explain the foundry industry's reluctance to try domestically-sourced minerals. The record with respect to domestic silica sands is dismal. Not only have foundries been unwilling to change, but most suppliers have by and large been quite content with U.S. products. There appears to be little economic incentive to invest in Canadian sand mining and processing in the face of very low U.S. costs, the product's excellent quality and geographic convenience. We do not believe that U.S. ownership dominance is a significant factor. It is, however, true that the three major auto manufacturers represent over 70% of Ontario silica sand usage in foundries and purchase centrally for both their U.S. and Canadian foundries. They buy directly from the primary producers and not through Canadian middlemen. This might be termed a structural barrier to the development of Canadian silica sand sources, but it should not be considered the major factor.

Bentonites and most refractory materials are not available in Ontario, according to the surveyed suppliers. For some refractory materials, this could change and there are efforts being made to source in Canada wherever possible. We expect to see a trend to more Ontario sourcing and processing of refractory materials.

The trend to more chemical binders will continue, although at a lower rate because the market is nearing saturation. Resinated sand disposal problems will also increase as the government toughens environment regulations.

SAND RECLAMATION

There are some opportunities for greater use of sand reclamation. Most of these must be justified by individual foundries and implemented on the merits of each individual case. Until reclamation technology is further developed, many foundries will not be able to justify it.

Central reclamation appears to be feasible in central Ontario. More detailed study is necessary to prove the case. In the U.S., this service is provided by private enterprise. We believe the Ontario foundry industry and its mineral suppliers are quite capable of undertaking central or cooperative reclamation facilities when demand and economics warrant them.

Appendix I. Survey of Ontario's Iron Foundries

A high response of 87% was obtained from the iron foundries. It was estimated that respondents represented over 95% of industry total capacity. Table I-1 summarizes the principal statistics provided by the 34 respondents.

OWNERSHIP

Only eight of the 34 respondents are foreign-owned firms, but they represent 56% of industry capacity in Ontario. Most of these firms are the automotive foundries, including Ford and General Motors. The Canadian-owned foundries tend to be smaller in size, but the larger operators such as Canron and Algoma Steel have well over 100,000 tons annual capacity.

TYPE OF FOUNDRY

The nine captive foundries are mostly foreign-owned. Included are the large foundries operated by the automobile manufacturers or their major suppliers and proprietary product firms such as Canron and Bibby St. Croix who make pipe and fittings. These captive foundries represent 61% of total industry capacity and 72% of industry output. This is up from the proportion in the mid 1970's when they were only 58% of industry output. Undoubtedly this increase is the result of strong automotive demand.

The number of jobbing foundries has declined over the past ten years from just over 35 to just under 30 in 1986. Smaller foundries have not been able to survive in the face of the high cost of modernization and market downswings.

OUTPUT

The 877,500 tons reported for 1985 represent a 30% increase over 1980 output. The increase comes entirely from the captive/proprietary segment, where it is a 44% increase. The jobbing foundries only increased by 3.5% over the 5-year period.

Ontario iron foundry output in the mid 1970's was approximately 1.0 million tons. The decline is due entirely to a 40% reduction in output of the jobbing foundries. Captive foundry output is up modestly by less than 10%. Declining output in the iron foundry industry is accounted for by a great number of factors, but the most important are re-design of cast parts to reduce weight, substitution by other materials and the elimination of castings in equipment design.

CAPACITY AND CAPACITY UTILIZATION

Just over 1.2 million tons of iron casting capacity were reported for 1985. This is an increase of only 6% since 1980. This is an increase of only 1.5% for the captive/proprietary foundries and

TABLE I-1. RESULTS OF SURVEY OF ONTARIO IRON FOUNDRIES.

1. Response				
Total Number Responding	34			
Total Mailed	39			
2. Ownership				
Canadian	26			
Foreign	8			
3. Type of Foundry				
Captive	9			
Jobbing	25			
4. Output (1000's tons)				
	1980		**1985**	
Captive/Proprietary	438		632	
Jobbing	237		245.5	
Total	675		877.5	
5. Capacity & Utilization (1000's tons)				
	1980		**1985**	
Captive/Proprietary	824.5	53%	836.5	76%
Jobbing	321.5	74%	379.0	65%
Total	1,146.0	59%	1,215.5	72%
6. Employment				
	1980		**1985**	
Captive/Proprietary	3,837		4,500	
Jobbing	2,873		2,602	
Total	6,710		7,102	

an increase of almost 18% for the jobbing foundries. Capacity utilization is well up, to 72%, due to the increase in output.

In a 1973 Ontario ferrous foundry study, reported capacity utilization was 81% for iron foundries, 63% for jobbing foundries and 85% for captive/proprietary foundries. Iron foundry capacity at that time was about the same as in 1985.

EMPLOYMENT AND PRODUCTIVITY

Ontario iron foundries employed 7,102 in 1985, up almost 6% from 1980. Productivity for 29 foundries who reported sufficient data in 1985 is $150,600 per employee. If the Ford and General Motors foundries are excluded, productivity for 27 foundries is $82,900 per employee. The range amongst jobbing foundries is $32,000 to $100,000 per employee.

For 1985, the employee size distribution of reporting foundries is as follows:

Size	No. of Firms
< 50 employees	9
50 - 100 employees	9
101 - 500 employees	14
> 500 employees	2
Total	34

Productivity amongst the smallest group of firms averages about $50,000 per employee, while in the two largest automotive foundries the average is well over $200,000 per employee.

SALES BREAKDOWN

Survey results are shown in Table I-2.

Casting Weights

About 50% of all iron foundry output is in castings of less than 50 pounds. This is a reflection of the automotive foundry, where from 60 to 100% of production is in under 50-pound castings. The size of the 100 to 500 pound category also reflects production by some of the automotive foundries as well as pipe plants. The largest category of over 1,000 pounds is influenced heavily by the Algoma and Canron Ingot Mould & Stool foundries.

Market Segments

The surge in the last few years of the automotive/truck business is evident in this foundry data. In the 1970's, this segment was typically around 50%. Jobbing markets in machinery, equipment and other manufacturing has not been strong in recent years. This was also true of the municipal/construction market until very recently.

TABLE I-2. RESULTS OF SURVEY OF ONTARIO IRON FOUNDRIES — SALES BREAKDOWN (ESTIMATED TONNAGE BASIS).

	1985 (%)
1. By Casting Weight	
0 - 50 lbs	50
50 - 100 lbs	12
100 - 500 lbs	23
500 - 1000 lbs	2
over 1000 lbs	13
Total	100
2. By Market Segment	
Auto/Truck	74
Municipal/Construction	6
Machinery & Equipment	5
All Other	15
Total	100
3. By Destination	
Ontario	64.7
Eastern Canada	1.9
Western Canada	0.6
U.S.	32.5
Other	0.3
Total	100.0
4. By Metal	
Gray	68
Ductile	30
Malleable	2
Total	100

By Destination

Again, the automotive foundries heavily influence the statistics. These foundries typically report virtually all their output going to Ontario and the United States — some on a 75% - 25% basis and others on a 10% - 90% basis respectively. Only 1/3 of the foundries reported shipments to eastern or western Canada.

By Metal

Production of ductile iron has been increasing over the years and now stands at about 30%. In the mid 1970's it was below 25%. Malleable iron is also declining.

FORECAST FOR 1990

Table I-3 summarizes forecast output in 1990.

Iron foundry respondents projected an increase of just under 10% from 1985 to 1990. The major automotive foundries projected only 8.5% while the other foundries forecast a slightly higher 13%.

Aside from the buoyancy of current automotive markets, this forecast reflects the optimism of most foundries with respect to penetrating U.S. markets. There is also a belief amongst most jobbing foundries that "things have to get better". Some of the major items in these forecasts are as follows:

- ☐ Expected cutbacks in Ingot Mould & Stool Production;
- ☐ Increases of 50% or more by 6 foundries;
- ☐ No increase by 7 foundries

TABLE I-3. RESULTS OF SURVEY OF ONTARIO IRON FOUNDRIES - OUTPUT FORECAST.

	1980	1985	1990
		(1000's tons)	
All foundries	675.0	877.5	962.0
Increase		+30.0%	+9.6%
Major auto only	373.0	658.9	715.0
Increase		+76.5%	+8.5%
Other foundries	301.9	218.6	247.0
Increase		-17.6%	+13.0%

The major issue regarding the future for iron foundries in Ontario is whether growth in automotive demand will continue. Will the decline in non-automotive, jobbing markets continue as it has elsewhere in North America? It is likely that automotive and other selective growth will offset declines and leave the market relatively flat over the next five years.

PROFITABILITY AND INVESTMENT

Table I-4 provides data on profitability, prices and investment.

Reported Profitability (Percentage of Sales)

The majority of foundries reported average to above average profits of about 7 - 10% on sales. This has been made possible by productivity improvements through capital expenditures and improved practices.

Jobbing prices have not kept pace with inflation, having grown only 7% in the five year period 1980 - 1985. Most foundries reported extreme pressure to keep prices down. Buyers have the bargaining position to force this situation on foundries. The projection to 1990 reflects the hope that the depressed pricing will not continue, although there is not strong evidence to back this forecast.

Investment Plans 1985 - 1990

Reporting foundries indicated that spending in the next 5 years would not remain at the level of that spent in the last 5 years. The decline is about 25%. Many of the foundries are already in an expansion mode and are finishing off in 1986 - 1987 work already started.

In comparison with capital investment in the 1970's, these figures indicate about half the spending level occurred in the early 1980's. In the period 1971 - 1975, it is estimated from the 1973 foundry study that about $100 million was invested. The only reason for this decline in investment is the negative feeling about the future evident in most non-automotive foundries.

TABLE I-4. RESULTS OF SURVEY OF ONTARIO IRON FOUNDRIES - PROFITABILITY & INVESTMENT.

1. Pretax Profit % of Sales	
	No. of Foundries
>15%	1
9-12%	6
5-8%	5
1-4%	3
Loss	3
2. Jobbing Prices	
	$ per Ton
1980	1075
1985	1150 (+ 7%)
1990	1500 (+ 30%)
3. Investment (28 Reporting)	
1981 - 85	$83.4 million
1986 - 90	$78.8 million (-5%)

There seems to be no other way of explaining the fact that foundries are only prepared to spend 1/5 of their profit level on modernizing and increasing the capacity of their plants.

There were a few foundries who spoke of the need to spend large amounts of money in the next year or so on environmental control equipment. The main complaint here was in respect to disposal of used sand, because the government has forbidden disposal without a license. It will be difficult to obtain a license to dispose of many chemically coated sands. Disposal costs, including cartage, have been calculated as high as $50 per ton.

MINERAL USAGE

Table I-5 provides some data on sand usage. While many respondents were able to give sand usage data, they were not able to provide binder, refractory or flux material usage which could be tabulated statistically.

Sand System

A great majority of iron foundries use a green sand moulding system. This is a clay-bonded system where the foundry usually mixes a silica or olivine sand with bentonite and water. This is the most economical system for volume foundries. Almost half the foundries have an air-set sand system which is a two or three-part organic chemical binding system which sets in ambient air temperatures. This is normally used for smaller volumes and larger castings.

For coring, the predominant system is shell sand or other chemical binding. The shell sand is coated with a phenolic resin hardened with heat. The shell sand is purchased on a coated basis by virtually all foundries. The older oil sand system is still in use as is the carbon dioxide, sodium silicate binder system where hardening is accomplished by carbon dioxide gas.

TABLE I-5. RESULTS OF SURVEY OF ONTARIO IRON FOUNDRIES - SAND USAGE.

1. Sand System	
	No. of Foundries
Moulding - Green	29
- Air Set	14
Core - Oil	13
- CO_2	8
- Shell	22
- Other Chemical	20
2. Sand Purchases 1985	
Total (30 foundries)	373,000 tons
Average Cost - Delivered	$25.60/ton
Average Freight Cost (included above)	$9.12/ton
Total Cost	$9.5 million

Sand Purchases

Thirty foundries reported 373,000 tons of sand were required to produce 841,100 tons of good iron castings, which on average is 44 tons of sand for every 100 tons of good casting. This usage figure is raised by the big automotive foundries. Excluding the three largest of them would mean the average for all other foundries dropped to 31.5 tons of sand required for 100 tons of good casting.

The sand on average cost $25.60 per ton delivered. If the automotive foundries are excluded, the cost would go up substantially to just under $50 per ton, because the big three automotive foundries buy directly and pay only on average $15 per ton.

Freight costs are a substantial part of this price for the automotive foundries, almost 50%, and for all other foundries about 25%, or just under $13 per ton.

While these tonnages of sand used are large, the cost is small in relation to the value of casting sales. For the 30 reporting foundries, the value of sand consumption is approximately 1% of the value of sales. For the major automotive foundries, the range is 0.5 to 1%, while other foundries typically range from 1 to 5%.

Other Mineral Purchases

Since binders, refractories and fluxes are far smaller purchases than sand, the foundries generally were not able to respond to our questionnaire. Much of the data that was provided is confusing, since there are many types of binders and refractory materials and they have many different applications in the foundry. The binders are particularly difficult in that many sands are sold on a premixed basis and of course shell sands are purchased already coated with a resin. The mineral suppliers themselves represent the only useful source of data on binders, refractories and fluxes.

Reclamation

Only 20% of the iron foundries have a reclamation system. In all cases this is a mechanical system, which is installed in smaller foundries. Costs of reclaiming sand vary, from about $3/ton to $15/ton. Several foundries are planning reclamation systems, but plans are not definite and depend on tons available, sand costs, disposable costs, and other factors.

Only about 10 of the iron foundries indicated interest in central reclamation. Most thought the idea impractical because of shipping costs to and from a central plant. There are also a number of technical problems with what kind of product might be available from a central reclamation plant and whether it could cause difficulties. Of the 10 affirmative foundries, only 2 or 3 are in a concentrated area of about 30 miles radius. It was surprising the number of respondents who had not thought about central reclamation and had no opinion. It would appear from the interviews that sand reclamation systems is an area about which many foundries know little and feel there is not much economic value in pursuing.

Appendix II. Survey of Ontario's Steel Foundries

Eleven of the 14 steel casting producers responded to the survey. The total capacity covered by the questionnaire represents an estimated 65% of the industry's total capacity. Table II-1, summarizes the principal statistics provided by the 11 respondents.

TABLE II-1. RESULTS OF SURVEY OF ONTARIO STEEL FOUNDRIES.

1. Response		
Total Number Responding		11
Total Number Mailed		14
2. Ownership		
Canadian		9
Foreign		2
3. Type of Foundry		
Captive		*
Proprietary		1
Jobbing		10
4. Capacity		
1985	44,990	tons/year
1980	59,820	tons/year
5. Output		
1985	26,858	tons
1980	51,272	tons
6. Capacity Utilization		
1985	**	67%
7. Employment		
1985	1134	-42%
1980	1951	
1985 Employment	**Number of Foundries**	
< 50	4	
50 - 100	4	
100 - 150	1	
150 - 200	0	
200 - 250	1	
250 - 300	0	
300 - 350	0	
350 - 400	1	

** Three of the foundries list themselves as captive, but more than 90% of their respective sales are to the jobbing market.*

*** One of the 11 foundries would not divulge output so the above represents 10 foundries with a total 1985 capacity of 40,180 tons.*

OWNERSHIP

The Ontario steel foundry industry is essentially owned by Ontario residents. One of the three non-participants was a subsidiary of a U.S. firm at the time of the survey, but has recently been taken over by a Canadian public company. The other two are under domestic ownership.

TYPE OF FOUNDRY

The three captive foundries who responded to the questionnaire sell 90% or more of their production to the jobbing market and have been included as jobbing foundries. One of the non-respondents produces proprietary products for the truck market.

CAPACITY

The decrease in capacity of 25% is entirely due to changes at Dofasco and Fahramet where the total capacity was decreased by 17,500 tons between 1980 and 1985. This down-sizing reflects declining demand for steel castings, as noted below. The total reported decrease was 14,830 tons. There was some increase in capacity in the other smaller foundries.

OUTPUT

One of the 11 respondents would not report shipments so that the data represents 10 foundries with a total capacity of 40,180 tons or approximately 58% of the total capacity. There has been a decrease in output of more than 24,000 tons or 48% since 1980. This decrease is mainly due to the weakness in two of the traditional major markets: railways and mining equipment.

CAPACITY AND CAPACITY UTILIZATION

Since some capacity has been withdrawn the utilization of plant capacity has not decreased in proportion to volume.

EMPLOYMENT AND PRODUCTIVITY

While output has decreased by 48%, employment has decreased by only 42%. Productivity has decreased from 26.3 tons per man year in 1980 to 23.7 in 1985.

SALES BREAKDOWN

Survey results providing sales breakdown are shown in Table II-2.

Casting Weights

Steel foundry production has shifted to larger sizes in recent years — 80% weigh more than 100 pounds. This is a reflection of the inroads made by ductile iron in the automotive/truck and farm machinery markets.

Market Segments

A breakdown of sales by market in 1980 would have been quite different. The railway segment would probably have accounted for at least 40% of the total sales and the mining industry would

TABLE II-2. RESULTS OF SURVEY OF ONTARIO STEEL FOUNDRIES - SALES BREAKDOWN (ESTIMATED TONNAGE BASIS).

1. By Casting Weight	1985 (%)
0 - 50 lbs	5
50 - 100 lbs	15
100 - 500 lbs	42
500 - 1000 lbs	16
> 1000 lbs	22
Total	100
2. By Market	
Automotive/Truck	26
Railway	25
Mining	11
Municipal/Construction	7
Valves & Pumps	6
Forest Products/Pulp & Paper	4
Other Machinery & Equipment	10
Petrochemical	4
All Other	7
Total	100
3. By Metal	
Irons	3
Carbon Steel	66
Manganese Steel	1
Low Alloy Steel	13
High All & Stainless	15
Non-Ferrous	2
Total	100

4. Shipments of Ontario Foundries by Destination

Percent Of Output	Number of Foundries				
	Ontario	E. Canada	W. Canada	U.S.	Other
nil	-	1	3	-	-
1 - 10	-	3	6	3	2
10 - 25	-	6	2	5	-
25 - 50	3	1	-	2	-
50 - 75	3	-	-	1	-
75 - 90	4	-	-	-	-
90 -100	1	-	-	-	-

have been at least 20%. It is the great decrease in these markets which is the principal cause of the reported decreases in capacity and output. The small jobbing foundries who are generally not involved in the abovementioned markets actually grew during the 1980 - 1985 period both in capacity and output. It is also interesting to note that this latter group exports an average of 30% of their output to the U.S.

FORECAST FOR 1990

Forecasts are summarized in Table II-3. The large foundries who are the traditional suppliers to the automotive/truck, railway and mining markets are forecasting an increase in shipments of 40% from 1985 to 1990 or an average of 7.4% per year. On the other hand, the small foundries serving other markets are forecasting growth of 23% or 4.5% annually.

TABLE II-3. RESULTS OF SURVEY OF ONTARIO STEEL FOUNDRIES - OUTPUT FORECAST.

	1980	1985	1990
		tons	
All Foundries	51,272	26,858	37,575
Increase		-48%	+40%
Major Auto/Truck, Railway & Mining	48,000	22,500	32,200
Increase		-47%	+47%
Other Foundries	3,270	4,358	5,375
Increase		+33%	+23%

An examination of Table II-3 suggests that the first group of foundries has not recovered from the recession, but feels it has bottomed out. The second group has definitely rebounded from the recession and forecasts slower subsequent growth.

It is interesting to note that even with the 8% annual growth foreseen by the large foundries, they will still ship about 1/3 less than they did in 1980, whereas the smaller foundries will ship 64% more in 1990 than 1980.

There is a marked difference between the sum of the individual forecasts made by the foundries and the forecasts provided by their suppliers. In addition, any forecast requires an estimate of attrition in the number of foundries and we were not able to obtain one. Much of the growth of individual foundries during the last 20 years has been due more to rationalization of the industry rather than growth of the markets.

PROFITABILITY AND INVESTMENT

Profitability data is shown in Table II-4. As one might expect, losses and low profitability were reported by the larger foundries engaged in volume production. Almost all the small specialty foundries were above average profitability, i.e., more than 5-8% return on sales. These foundries usually operate at a lower level of capacity utilization, since they need extra facilities for flexibility in producing a wide range of products.

There is a very wide gap in prices for the volume products and for the short-run special castings. However, price increases are expected in each case. This again is at variance with the opinions of the mineral supply industry.

Most of the investment planned for the next 5 years is to maintain or upgrade existing equipment. Other objectives are to improve productivity and/or quality. Very little will be invested to increase capacity. However, some of the smaller foundries are investing to produce higher grade and higher priced products.

MINERAL USAGE

Sand data is shown in Table II-5.

TABLE II-4. RESULTS OF SURVEY OF ONTARIO STEEL FOUNDRIES - PROFITABILITY & INVESTMENT.

1. Pretax Profit as % of Sales			
		Number of Foundries	
	Over 15%	1	
	9% - 12%	1	
	5% - 8%	3	
	1% - 4%	2	
	Loss	3	
2. Jobbing Prices			
	Major Auto/Truck, Railway		
	$/ton		
	1980	1,930	
	1985	2,240	+ 16%
	1990	2,400	+ 7%
	All Other	**$/ton**	
	1980	7,000	
	1985	7,700	+ 10%
	1990	8,500	+ 10%
3. Investment (10 reporting)			
	1981 - 85	$17.5 million	
	1985 - 90	$15.0 million	-14%

TABLE II-5. RESULTS OF SURVEY OF ONTARIO STEEL FOUNDRIES - SAND SYSTEMS.

1. Type of System		**Number of Foundries**
Mouldings -	Green	6
	Air-Set	10
	CO_2	1
	Shell	2
	Ceramic	3
	Permanent	2 (centrifugal castings)
Coremaking -	Oil Sand	6
	CO_2	4
	Shell	7
	Other Organic Binders	10
	Ceramic	2
	Permanent	1
2. Sand Purchases		
Total (11 foundries)		20,800 tons
Average Cost-Delivered		$56.98/ton
Average Freight Cost (included above)		$19.29
Total Cost		$1.2 million
3. Reclamation Systems		
Air-Set Moulding		10 foundries
Reclamation Systems		9 foundries
Type - Mechanical		9
- Thermal		0
Total Capacity (7 reporting)		139,000 tons
Average Recovery		76.1%
Average Cost of Recovery		$6.39/ton
4. Sand Consumption (tons/ton of product)		
	Number of Foundries	
<0.5	5	
0.5 - 1.0	2	
>1.0	2	
Averages -	1980 - 1.41 (8 foundries)	
	1985 - 0.80 (9 foundries)	

Sand Systems

All the commonly known moulding and core systems are in use. Many of the foundries use 2 or 3 moulding systems. Similarly, most foundries use at least three core systems. It appears that air-set moulds and organically bonded cores are becoming predominant in the small specialty foundries.

Sand Purchases

Most of the steel foundries use Ottawa (Illinois) silica or equivalent sands plus small amounts of olivine, zircon and chromite. In all but one case the sand is purchased from an Ontario supplier, although sourced in the U.S. The transportation cost represents the shipping cost from Hamilton. The cost of shipping from Ottawa, Illinois to Hamilton is included in the supplier's price with his costs, overhead and margin. A typical example would be:

Cost at the mine	$14 (Canadian)
Freight to Hamilton	16
Supply House Charges, including margin	8
Total (per ton)	$38

Reclamation

All but one of the foundries using an air-set moulding system have mechanical reclamation plants. The average recovery of 76% falls short of the minimum levels claimed by the manufacturers (85-90%). In some cases a relatively high recovery has been reported, but the reclaimed sand is limited to backing or other non-critical applications. Taking this into account, the true reclamation rate is much lower than 76%. Considering the cost of the sand and the disposal costs, a recovery rate of 76% or less leaves considerable room for improvements.

Sand Consumption

The data derived from the survey shows that the Ontario steel foundry industry is following the general trend to lower sand consumption per ton of product.

Appendix III. Survey of Ontario's Non–Ferrous Foundries

Twenty of the 41 non–ferrous foundries responded to the survey. This represents approximately 50% of the industry's total capacity. Very few of the non–ferrous foundries belong to the Canadian Foundry Association or other industry associations and generally are not supportive of statistical surveys. Table III–1 summarizes the principal statistics provided by the 20 respondents.

OWNERSHIP

Of the respondents, 75% are Canadian owned. Most of the foreign– owned firms are captive foundries in plumbing brass. Two of the Canadian–owned companies are public companies. It is believed this ownership breakdown is representative of the non–respondent group as well, except that most of the non–respondent foreign–owned group are captive automotive and electrical aluminum foundries.

TYPE OF FOUNDRY

Only 4 of the 20 respondents are captive foundries, but they are large operations. They include:

- Crane Canada
- EMCO
- Cambridge Brass (EMCO Subsidiary)

The respondent captive foundries represent 30% of total capacity reported. This is probably representative of the non–respondent group since major captive aluminum foundries such as Ford of Canada, West Bend and others did not report.

TABLE III–1. RESULTS OF SURVEY OF ONTARIO NON–FERROUS FOUNDRIES.

1. Response					
Total Number Responding		20			
Total Mailed		41			
2. Ownership					
Canadian		15			
Foreign		5			
3. Type of Foundry					
Captive		4			
Jobbing		16			
4. Output (tons)		**1980**		**1985**	
Captive -	Cu–Based	* 3,000		5,800	
Jobbing -	Cu–Based	** 751		3,436	
	Aluminum Based	6,260		9,020	
Total		10,011		18,256	
5. Capacity & Utilization (tons)					
		1980		**1985**	
Captive -	Cu–Based	* 5,950	50%	9,200	63%
Jobbing -	Cu–Based	** 1,466	51%	5,801	59%
	Aluminum Based	9,495	66%	14,905	61%
Total		16,911	59%	29,906	61%

6. Employment 1985 - 18 Foundries Only

		Jobbing		
Employees	**Captive Cu–Based**	**Cu–Based**	**Alum. Based**	**Total Employment**
< 50	1	4	4	196
50 - 100	1	2	-	212
100 - 300	2	-	3	910
> 300	-	-	1	380
Total No. of Foundries	4	6	8	
Total Employment	458	207	1033	1698

* *Two foundries only*
** *Four foundries only*

OUTPUT

In total, respondents reported 18,263 tons of output, or 36.5 million pounds. We estimate that total output of Ontario non-ferrous foundries in 1985 was:

Copper-based	30 million pounds
Aluminum-based	75 million pounds

This is up substantially from 1975 when the total output was:

Copper-based	21 million pounds
Aluminum-based	13 million pounds

Total shipments by the industry have likely almost doubled over the past ten years, with the greatest growth being in aluminum casting shipment which have more than doubled.

CAPACITY AND CAPACITY UTILIZATION

Almost 30,000 tons, or 60 million pounds of capacity were reported to us. Overall capacity utilization for 1985 is 61%. This is up modestly from 59% utilization in 1980. However, capacity has increased substantially over the period or just under 50% for those foundries which reported both years. The increase for aluminum foundries is close to 50% while that for copper-based foundries is only 35%.

EMPLOYMENT AND PRODUCTIVITY

Only 18 foundries reported employment data and many did not give 1980 comparison figures. Of the 18 foundries reporting, 9 had under 50 employees, with an average representing only 20 employees each. The great bulk of the non-respondent firms would be in this category, about 15 to 20 of them. Larger firms with over 100 employees represented 6 or 33% of our respondents, but accounted for just over 75% of employment. While 1980 comparisons are not available, it is inevitable from individual returns that productivity has improved considerably. The average productivity reported for 1985 was $58,600 per employee, while a comparable estimate for 1980 is $43,000 per employee. Productivity for the high value-added and high integrity foundries in 1985 goes as high as $100,000 per employee.

SALES BREAKDOWN

Survey results are shown in Table III-2.

Casting Weights

Non-ferrous castings are much smaller than ferrous castings. The copper-based industry is dominated by the plumbing-brass foundries which have virtually all their production in under 20 pound castings. Most of the larger castings in the 500 -1000 pound category are large bearings. The aluminum-based industry is even more dominated by smaller castings.

TABLE III-2. RESULTS OF SURVEY OF ONTARIO NON-FERROUS FOUNDRIES - SALES BREAKDOWN. (ESTIMATED TONNAGE BASIS).

	1985	
1. By Casting Weight	**Copper-Based**	**Aluminum-Based**
	(%)	(%)
0 - 50 lbs	89	89
51 - 100 lbs	3	8.5
101 - 500 lbs	2	2.5
501 - 1000 lbs	4	0
> 1000 lbs	1	0
Total	100	100
2. By Market Segment		
	(%)	(%)
Auto/Truck	1	17
Valves/Pumps	17	8
Machinery/Equipment	10	21
Plumbing	59	1
Electrical	5	27
All Other	9	26
Total	100	100
3. By Destination		
	(%)	(%)
Ontario	42	76
Eastern Canada	16	5
Western Canada	30	1
U.S.	12	16.5
Other	-	1.5
Total	100	100

Market Segments

The copper-based foundries are dominated by the plumbing-brass firms who in our response represent almost 60%. This is not representative of the industry as a whole which should probably be closer to 40% plumbing brass. The next largest category is in valves and pump components which are 17%. Valves and pumps with machinery at 10% are likely understated by as much as half. They probably, in fact, represent close to 50% of the total copper-based industries output, since valves, pump impellers and bushings or bearings are a major output of the copper-based industry.

The aluminum-based industry sells a great many electrical components, as well as machinery parts. The automotive sector has been growing rapidly and is understated here because the Ford Canada aluminum casting plant is not included.

By Destination

Ontario is, as expected, the dominant market. For copper-based foundries, one plumbing-brass firm sells a great deal of its production to western Canada and greatly influences the breakdown. All non-ferrous foundries are increasing their shipments to the U.S. as U.S. non-ferrous foundries close down.

FORECAST FOR 1990

Table III-3 summarizes forecast information. Respondents were optimistic in their forecast, although many felt very uncertain about the future and, in fact, supplied more of an objective of what they would like the volume to be in 1990 than a realistic forecast. At least one major copper-based foundry said that they must grow by 67% or close down. A great deal of stock was not placed in these projections since their suppliers are much more pessimistic. Copper-based foundry suppliers consider the market will be flat or decline somewhat. Aluminum industry suppliers feel there will be modest growth.

U.S. Growth Trends

U.S. production of copper-based castings has been declining for some time and the rate of decline appears to be increasing in recent years. While the long term decline is 1 - 2% per year, in the last 5 years it is close to 3% on average. For aluminum-based foundries the long term growth rate is 4 - 5% per year, but in recent years it has been increasing due to increased use of aluminum in automobiles. However, plastics and composites are likely to threaten this in the longer term future.

Canadian Market Trends

Most of the responding foundries felt that U.S. exports were a major opportunity which they have just started to cultivate. In fact, it is U.S. shutdowns of captive foundries that appears to have provided much of the opportunity for progressive Canadian foundries. We believe the Ontario non-ferrous foundries are experiencing a cyclical peak due to strong demand from the construction industry for plumbing brass and automotive castings. It was concluded that the following average annual growth rates for 1985-1990 are more realistic:

Copper-based	+ 2-3% per year
Aluminum-based	+ 5-7% per year

TABLE III-3. RESULTS OF SURVEY OF ONTARIO NON-FERROUS FOUNDRIES - 1990 FORECAST.

1. 1990 Output Forecast by Respondents

	Cu-Based	Aluminum-Based	Total
		(tons)	
1980	N/A	6,260	N/A
1985	9,236	9,020	18,236
1990	14,400	13,650	28,050
% Increase			
1985-90	+56%	+51%	+54%

2. U.S. Growth Trends

	Cu-Based	Aluminum-Based	Total
		(tons 000)	
1960	380	387	767
1970	375	753	1,128
1980	286	845	1,131
1985	235	1,114	1,349
% Average			
Growth/Year	-1.4%	+4.5%	+3.2%

3. Canadian Major Market Trends

Cu-Based:	Plumbing Brass	flat/down
	Bushings/Bearings	flat/down
Aluminum-Based:	Automotive	up modestly
	Electrical	up modestly
Exports to U.S.		up

PROFITABILITY AND INVESTMENT

Table III-4 provides respondent data on profitability and capital expenditures. Only 12 of the 20 responding firms provided profitability data. The captive foundries have considerable difficulty calculating profitability because the foundry is only a department of a larger manufacturing operation. They are not generally profit centres in themselves. Most of the profitability responses were approximate estimates only. Both the copper and aluminum-based segments show average profitability of approximately 8%, which is not out of line with the overall average reported in the 1975 study of the non-ferrous foundry industry in Ontario.

Investment Plans

Only 8 firms provided useful capital expenditure data. The 8 copper-based firms had 1985 sales of about $32 million. In the 1981-1985 period they spent about $1.6 million per year or approximately 5% of sales. Thus, they spent an amount approximately equal to their likely after-tax profits. Most of them will spend slightly less than this in the next 5 year period to 1990 although they all had considerable difficulty in projecting capital expenditures. Feelings about the future are uneasy because of import threats and the high cost of improving productivity.

The 8 aluminum-based foundries reported just over $23 million in capital expenditures 1981-1985. Their sales in 1985 were about $77 million. This represents about 6% of sales on average in each year. This is somewhat more than after-tax

TABLE III-4. RESULTS OF SURVEY OF ONTARIO NON-FERROUS FOUNDRIES - PROFITABILITY & INVESTMENT.

1. Reported Profitability as % of Sales

	1985 Operating Profit/Sales *			
	<5%	5-7%	8-10%	>10%
		(No. of Firms)		
Cu-Based	1	1	2	1
Aluminum-Based	1	1	2	1

2. Investment Plans 1985-1990

	Spent 1981-85	Plan 1986-90
	($ millions)	
Cu-Based (8 firms)	8.0	6.2
Aluminum-Based (8 firms)	23.4	21.8

** before tax and interest*

profits. For the aluminum-based foundries, there is somewhat more optimism about the future, but again, investment plans appear to include only productivity improvements and not much capacity increase.

All non-ferrous foundry respondents are concerned about upcoming Ontario legislation with respect to environmental controls and capital spending that will be required thereby.

MINERAL USAGE

Table III-5 provides what little mineral usage data is available. Very few foundries gave useful data as shown in the table.

Sand

Sand consumption data was highly variable and ranged from almost 1 ton of sand consumed for each ton of good castings to 1 ton of sand for 10 tons of good castings. The average is much lower for aluminum-based foundries since widespread use of permanent moulds is made. Sand costs are very low in relation to sales, since average realizations per ton of non-ferrous castings are $4,000 to $6,000 for most foundries. This places the cost of sand at only 2 or 3% of sales.

Bentonite

Only 4 foundries reported here and even for these only approximate data was provided. Green sand is still the most common moulding system for non-ferrous foundries and bentonite is generally used in a 3-10% proportion.

Organic Resin

The majority of non-ferrous foundries use organic chemical binders in their core sand systems. Evidence was seen of the continuing shift to these binders for coring work, although environmental control regulations may inhibit future growth in demand because sand disposal problems could become critical.

Non-ferrous foundries could not be persuaded to provide refractory consumption information.

None of the non-ferrous foundries were interested in sand reclamation systems either for themselves or central reclamation.

TABLE III-5. RESULTS OF SURVEY OF ONTARIO NON-FERROUS FOUNDRIES - MINERAL USAGE.

1. Sand Usage 1985

	Sand Consumption (tons)	Castings Output	Ratio
Cu-Based (6 firms)	649	2,900	0.22
Aluminum-Based (6 firms)	514	7,120	0.072

2. Bentonite Usage 1985

	Bentonite Consumption	Sand Consumption (tons)	Castings Output
Cu-Based (2 firms)	32	270	1,280
Aluminum-Based (2 firms)	7	285	670

3. Organic Resin Usage 1985

Cu-Based	10 of 12 use resin for core sand
Aluminum-Based	6 of 8 use resin for core sand

Appendix IV. Foundries in Ontario (1986)

FERROUS FOUNDRIES

The Algoma Steel Corporation Limited
503 Queen Street East
Sault Ste. Marie, Ontario
P6A 2A2
Tel. (705) 945-2333
Iron and Steel

Alloy Casting Industries Ltd.
P.O. Box 580
374 Hamilton Road
New Hamburg, Ontario
N0B 2G0
Tel. (519) 662-3111
Iron and Steel

Alloy Foundry Company Limited
P.O. Box 130
Merrickville, Ontario
K0G 1N0
Tel. (613) 269-4755
Iron

A.G. Anderson Ltd.
P.O. Box 6006, Station D
3040 Osler Street
London, Ontario
N5W 5R6
Tel. (519) 455-5420
Iron and Steel

Beaver-Delta Machinery Corp.
P.O. Box 848
40 Wellington Street
Guelph, Ontario
N1H 6M7
Tel. (519) 836-2840
Iron

Bell City Foundry Ltd.
411 West Street
Brantford, Ontario
N3R 3V9
Tel. (519) 753-2651
Iron

Benn Iron Foundry Limited
4 Mason Street
Wallaceburg, Ontario
N8A 4M1
Tel. (519) 627-3314
Iron

Bibby-Ste-Croix Limited
P.O. Box 279
Cambridge, Ontario
N1R 5T8
Tel. (519) 621-8410
Iron

Birla Industries Inc.
Walker Industrial Park
P.O. Box 3400
Windsor, Ontario
N8N 3C4
Tel. (519) 944-5554
Iron

Black Clawson-Kennedy Ltd.
1144 First Avenue West
Owen Sound, Ontario
N4K 4K9
Tel. (519) 376-8860
Steel and Iron

Bowmanville Foundry Co. Ltd.
Scugog Street
P.O. Box 69
Bowmanville, Ontario
L1C 3K8
Tel. (416) 623-3313
Iron

Brown Boggs Foundry & Machine Co. Ltd.
275 Sherman Avenue North
P.O. Box 3004, Station B
Hamilton, Ontario
L8L 7Y2
Tel. (416) 549-6594
Iron

Brown Foundry Ltd.
Industrial Road
Box 778
Morrisburg, Ontario
K0C 1X0
Tel. (613) 543-2944
Iron

Burnstein Castings Limited
69 Catherine Street
St. Catharines, Ontario
L2R 5E9
Tel. (416) 688-2022
Iron and Steel

C.S. Castings Industries Ltd.
P.O. Box 247
300 Matchedash Street
Orillia, Ontario
L3V 6J6
Tel. (705) 325-1338
Steel

Canada Alloy Castings Ltd.
529 Manitou Drive
Kitchener, Ontario
N2C 1S2
Tel. (519) 893-1161
Steel

Canron Inc., Foundry Division
3050 Harvester Road
Burlington, Ontario
L7N 3K7
Tel. (416) 681-1221
Iron

Canron Inc., Foundry Division
Ingot Mould Foundry
Burlington Street Plant
Burlington Street at Kenilworth
Hamilton, Ontario
L8N 3C8
Tel. (416) 547-5810
Iron

Canron Inc., Foundry Division
St. Thomas Plant
1010 Talbot Street
St. Thomas, Ontario
N5P 1G2
Tel. (519) 631-0820
Iron

Canron Inc., Pipe Division
101 Queensway West
Mississauga, Ontario
L5B 2P7
Tel. (416) 276-7311

Plant Location
Pipe Division
324 Cherry Street
Toronto, Ontario
M5A 3L2
Iron

Corbron Foundries Ltd.
P.O. Box 1119
Cornwall, Ontario
K6H 5V2
Tel. (613) 938-9221
Iron

Crouse-Hinds Canada Ltd.
1160 Birchmount Road
Scarborough, Ontario
M1P 2B9
Tel. (416) 757-8781
Iron

Crowe Foundry Limited
95 Sheffield Street
P.O. Box 9
Cambridge, Ontario
N3C 2V6
Tel. (519) 685-9376

Iron

Cunningham Foundry and Machine Co. Ltd.
21 Yale Crescent
St. Catharines, Ontario
L2R 2Y6
Tel. (416) 685-6577

Iron

Dart Foundries Limited
P.O. Box 160
Eagle Street
Stevensville, Ontario
L0S 1S0
Tel. (416) 382-3106

Iron

Date Industries Limited
Swan Street
Ayr, Ontario
N0B 1E0
Tel. (519) 632-7183

Iron

Dayton-Walther Co. Ltd.
355 Silvercreek Parkway
Guelph, Ontario
N1H 3E6
Tel. (519) 824-6350

Iron and Steel

Domestic Foundry Ltd.
1595 Crawford Avenue
Windsor, Ontario
N8X 2A9
Tel. (519) 254-1121

Iron

Dofasco Inc.
1330 Burlington Street East
P.O. Box 460
Hamilton, Ontario
L8N 3J5
Tel. (416) 544-3761

Steel

Dorcon Division
Dorr-Oliver Canada Limited
174 West Street South
Orillia, Ontario
L3V 6L4
Tel. (705) 325-6181

Iron

Emhart Canada Ltd.,
International Hardware Division
P.O. Box 396
180 Coleman Street
Belleville, Ontario
K8N 5A8
Tel. (613) 962-5311

Steel

Esco Ltd.
1530 Markham Road, Suite 400
Scarborough, Ontario
M1B 3G4
Tel. (416) 299-9660
Tel. (416) 885-6301

Plant address
Esco Ltd., Port Hope Foundry
P.O. Box 270
Port Hope, Ontario
L1A 3W4

Steel

Fahramet Steel Castings
25 Commerce Drive
P.O. Box 1700
Orillia, Ontario
L3V 6L6
Tel. (705) 325-2781

Steel

J.R. Fergusson Co. Ltd.
Hope Street
P.O. Box 8588
Dundas, Ontario
L9H 5G1
Tel. (416) 628-8521

Iron

Findlay Foundry Ltd.
Industrial Avenue
P.O. Box 250
Carleton Place, Ontario
K7C 3P4
Tel. (613) 257-5577

Iron

Fittings (1980) Inc.
135 Bruce Street
Oshawa, Ontario
L1H 1R1
Tel. (416) 723-3433

Iron

Ford Motor Company of Canada Ltd.
Windsor Casting Plant
2950 Metcalfe Street
P.O. Box 1620, Station A
Windsor, Ontario
N9A 4M1
Tel. (519) 257-4000

Iron

Galtaco Inc.
Powerline Road
P.O. Box 1930
Brantford, Ontario
N3T 5W5
Tel. (519) 759-0181

Iron

General Motors of Canada Ltd.
Foundry Division
570 Glendale Avenue
P.O. Box 3002
St. Catharines, Ontario
L2R 7B3
Tel. (416) 685-2401

Iron

Georgian Bay Foundry Limited
17 Trowbridge Street
P.O. Box 360
Meaford, Ontario
N0H 1Y0
Tel. (519) 538-3181

Iron

Hamilton Foundry Co. Limited
33 Clinton Street
P.O. Box 335, Station B
Hamilton, Ontario
L8L 7W2
Tel. (416) 544-0740

Iron

John T. Hepburn Limited
914 Dupont Street
Toronto, Ontario
M6H 1Z2
Tel. (416) 534-8871

Iron

Holmes Foundry Limited
200 Exmouth Street
P.O. Box 970
Sarnia, Ontario
N7T 5M5
Tel. (519) 336-8860

Iron

Hopper Foundry (1977) Ltd.
2 Clyde Street
P.O. Box 29
Forest, Ontario
N0N 1J0
Tel. (519) 786-2641

Iron

ITT Aimco Division
Division of ITT Industries of Canada Ltd.
152 Berryman Avenue
P.O. Box 1087
St. Catharines, Ontario
L2R 7A3
Tel. (416) 688-1754

Iron

ITT Grinnell
Division of ITT Industries of Canada Ltd.
2440 Dundas Street West
Toronto, Ontario
M6P 1X1
Tel. (416) 534-9571

Iron

H. Imbleau and Sons Ltd.
11 Bridge Street North
Renfrew, Ontario
K7V 3R1
Tel. (613) 432-2622

Iron

International Malleable Iron Co. Ltd.
200 Beverley Street
P.O. Box 180
Guelph, Ontario
N1H 6K1
Tel. (519) 836-2560

Iron

Johnson Matthey Ltd.
Foundry Division
16 Smith Street
P.O. Box 367
St. Catharines, Ontario
L2R 6T7
Tel. (416) 682-9258

Steel and Iron

Kanmet (Division of Massey Ferguson Industries Ltd.)
633 Margaret Street
P.O. Box 3220
Cambridge, Ontario
N3H 4S9
Tel. (519) 653-7121

Iron

Kelsey-Hayes Canada Ltd.
Woodstock Division
P.O. Box 300, Beard's Lane
Woodstock, Ontario
N4S 7X8
Tel. (519) 537-2331

Iron

Lake Foundry & Machine Co. Ltd.
287 South Service Road
Grimsby, Ontario
L3M 1Y6
Tel. (416) 643-1248

Iron

Magnaloy Co. Ltd.
10 Pine Street
Stratford, Ontario
N5A 1W3
Tel. (519) 273-2330

Steel

Massey Ferguson Industries Ltd.
Foundry Division
Greenwich Street
P.O. Box 370
Brantford, Ontario
M6K 1E3
Tel. (519) 758-2404

Iron

Archie McCoy (Hamilton) Ltd.
McCoy Foundry Company
R.R. 1
Troy, Ontario
L0R 2B0
Tel. (519) 647-3411

Iron

McLean Foundry Limited
247 Colbourne Street West
P.O. Box 1263
Brantford, Ontario
N3T 5T3
Tel. (519) 753-3468

Iron

Neelon Castings Limited
R.R. 1, Foundry Street
P.O. Box 2007, Station A
Sudbury, Ontario
P3A 4R8
Tel. (705) 566-1610

Iron

Norcast Inc.
Suite 208
68 Yonge Street
Toronto, Ontario
M5E 1L1
Tel. (416) 869-1087

Iron

Norcast Ltd.
New Liskeard Foundry
Wabi Iron Works
300 Broadwood Avenue
New Liskeard, Ontario
P0J 1P0
Tel. (705) 647-4383

Iron

Northern Ontario Castings Ltd.
P.O. Box 505
Orillia, Ontario
L3V 6S1
Tel. (705) 645-8441

Foundry Location
Entrance Drive
P.O. Box 2146
Bracebridge, Ontario
P0B 1C0
Tel. (705) 645-8741

Iron

Orangeville Foundry Ltd.
R.R. 4
Orangeville, Ontario
L9W 2Z1
Tel. (519) 941-1507

Iron

Port Arthur Shipbuilding Ltd.
P.O. Box 2690, Station P
Thunder Bay, Ontario
P7B 5G2
Tel. (809) 683-6261

Iron

Procast Foundries Ltd.
19 Church Street East
Elmira, Ontario
N3B 2K9
Tel. (519) 669-5424

Iron

Redlaw Industries Inc.
Orillia Foundry Division
255 West Street South
Orillia, Ontario
L3V 6L3
Tel. (705) 325-6121

Iron

Snowdon's General Castings Ltd.
315 Grey Street
Brantford, Ontario
N3T 5L5
Tel. (519) 753-1238

Iron

Specialty Cast Metals Ltd.
3635 Progress Street
P.O. Box 2126
Niagara Falls, Ontario
L2E 6Z2
Tel. (416) 357-0550

Steel

Standard Induction Castings Limited
3827 Peter Street
Windsor, Ontario
N9C 1K3
Tel. (519) 253-2446

Iron

Stanton Pipes Limited
Kennilworth Avenue North
P.O. Box 849
Hamilton, Ontario
L8N 3N9
Tel. (416) 678-9936

Iron

Stittsville Foundry Limited
340 Orville Street
P.O. Box 69
Stittsville, Ontario
K0A 3G0
Tel. (613) 836-1328

Iron

Summerstown Metals Ltd.
Summerstown, Ontario
K0C 2E0
Tel. (613) 931-1110

Iron

Welland Iron and Brass Ltd.
130 Niagara Street
Welland, Ontario
L3C 1J3
Tel. (416) 735-5676

Iron

Wells Foundry Limited
1250 Florence Street
London, Ontario
N5W 2N4
Tel. (519) 451-3620

Iron

Western Foundry Co. Ltd.
P.O. Box 460
Wingham, Ontario
N0G 2W0
Tel. (519) 357-3450

Iron

Woodside Machinist and Foundry Ltd.
173 Manitou Street
P.O. Box 2861
Thunder Bay, Ontario
P7B 5G3
Tel. (807) 344-1451

Iron

Wotherspoon Foundry Ltd.
148 Cross Street
P.O. Box 400
Oakville, Ontario
L6J 5A8
Tel. (416) 845-2873

Iron

NON-FERROUS FOUNDRIES

The Algoma Steel Corporation Ltd.
503 Queen Street West
Sault Ste. Marie, Ontario
P6A 5P2
Tel. (705) 945-2850

Copper Base

Alloy Foundry Co. Ltd.
P.O. Box 130
Merrickville, Ontario
K0G 1N0
Tel. (613) 269-4755

Aluminum & Copper Base

Alumaloy Castings Limited
483 Eastern Avenue
Toronto, Ontario
M4M 1C2
Tel. (416) 690-0673

Aluminum

Aluminum Mold & Pattern Inc.
50 Irondale Drive
Weston, Ontario
M9L 1R8
Tel.

Aluminum

Aluminum Star Products Ltd.
175 College Street West
Belleville, Ontario
K9N 5A2
Tel. (613) 962-8631

Aluminum & Copper Base

Artcast Inc.
14 Armstrong Avenue
Georgetown, Ontario
L7G 4R9
Tel. (416) 457-9501

Aluminum & Copper Base

Brampton Foundries Ltd.
7 Selby Road
Brampton, Ontario
L6W 1J5
Tel. (416) 453-6044

Aluminum Base

Burnstein Castings Ltd.
69 Catherine Street
St. Catharines, Ontario
L2R 5E9
Tel. (416) 684-8588

Aluminum & Copper Base

Cambridge Brass
Division of Waltec Industries Ltd.
P.O. Box 249
140 Orion Place
Cambridge, Ontario
N1R 5V1
Tel. (519) 621-5520

Copper Base

Cello Products Inc.
P.O. Box 37
210 Avenue Road
Cambridge, Ontario
N1R 5S9
Tel. (519) 621-9150

Copper Base

Chrysler Canada Limited
Etobicoke Casting Plant
15 Brown's Line
Toronto, Ontario
M8W 3S3
Tel. (519) 973-2000

Aluminum Base

Corbron Foundries Ltd.
P.O. Box 1119
Cornwall, Ontario
K6H 5V2
Tel. (613) 938-9221

Aluminum & Copper Base

Crouse-Hinds Co. of Canada Ltd.
1160 Birchmount Road
Scarborough, Ontario
M1P 2B9
Tel. (416) 757-8781

Aluminum Base

Custom Aluminum Foundry
P.O. Box 2092
Cambridge, Ontario
N3C 2V6
Tel. (519) 658-5173

Aluminum Base

DGM Foundry Ltd.
P.O. Box 91, Station B
London, Ontario
N6A 4V3
Tel. (519) 434-7626

Aluminum, Copper & Zinc Base

Dunbar Aluminum Foundry
Division of Ramsden Industries Ltd.
315 Breithaupt Street
Kitchener, Ontario
N2H 5H6
Tel. (902) 469-0981

Aluminum Base

Ekco Canada Inc.
376 Birchmount Road
Scarborough, Ontario
M1K 1M5
Tel. (416) 691-2156

Aluminum Base

Emco Limited
P.O. Box 5300, Terminal A
1108 Dundas Street East
London, Ontario
N6A 4N7
Tel. (519) 451-1250

Copper Base

Emhart Canada Ltd.
International Hardware Division
P.O. Box 396
180 Coleman Street
Belleville, Ontario
K8N 5A8
Tel. (613) 962-5311

Aluminum & Copper Base

Eramosa Brass and Aluminum Ltd.
120 Dawson Road
Guelph, Ontario
N1H 1A6
Tel. (519) 824-7121

Aluminum & Copper Base

Fisher & Son Limited
P.O. Box 9171
486 Arvin Street
Stoney Creek, Ontario
L8G 3X9
Tel. (416) 662-4187

Copper Base

Ford Motor Co. of Canada Ltd.
Essex Aluminum Plant
P.O. Box 1629
6500 Cantelon Drive
Windsor, Ontario
N9A 6X8
Tel. (519) 944-8500

Aluminum Base

G.S.P. Management Ltd.
P.O. Box 52
South Lancaster, Ontario
K0C 2C0
Tel. (514) 879-1129

Aluminum & Copper Base

Gamma Foundries Ltd.
75 Newkirk Road
Richmond Hill, Ontario
L4C 3G1
Tel. (416) 884-8992

Aluminum & Copper Base

Grenville Castings Ltd.
Montague Street
Merrickville, Ontario
K0G 1N0
Tel. (613) 269-4701

Aluminum Base

Haley Industries Limited
Haley, Ontario
K0J 1Y0
Tel. (613) 432-8841

Aluminum & Magnesium Base

H & E Castings Ltd.
240 Bunting Road
St. Catharines, Ontario
L2M 3X1
Tel. (416) 682-1850

Aluminum & Copper Base

Hamilton Matchplate Company
265 Lottridge Street North
Hamilton, Ontario
L8L 6W1
Tel. (416) 545-7684

Aluminum Base

Harrington Aluminum Foundry Ltd.
145 Main Street
Woodstock, Ontario
N4S 1T1
Tel. (519) 537-6711

Aluminum Base

Hoselton Studios
P.O. Box 130
Colborne, Ontario
K0K 1S0
Tel. (416) 355-3933

Aluminum & Copper Base

JCM Non Ferrous Foundry Ltd.
110 Ormond Street
Thorold, Ontario
L2V 4V6
Tel. (416) 227-4240

Aluminum & Copper Base

John's Aluminum and Brass Foundry
P.O. Box 1082
34 Charlton Avenue
Brantford, Ontario
N3T 5S7
Tel. (514) 752-6850

Aluminum & Copper Base

Johnson Matthey & Mallory Limited
Foundry Division
P.O. Box 367
16 Smith Street
St. Catharines, Ontario
L2R 6T7
Tel. (416) 682-9258

Aluminum & Copper Base

K.P. Bronze Company Ltd.
20 Allaura Boulevard
Aurora, Ontario
L4G 3S5
Tel. (416) 881-1568

Copper Base

Kerns Foundry Inc.
R.R. 3
Windsor, Ontario
N9A 6T6
Tel. (519) 734-1115

Aluminum, Copper, Lead & Zinc Base

Long Branch Foundry Ltd.
1062 Rangeview Road
Mississauga, Ontario
L5E 1H3
Tel. (416) 274-7200

Aluminum & Copper Base

Jas. H. Matthews & Co. Limited
71 Nipissing Road
Milton, Ontario
L9T 1R4
Tel. (416) 878-2358

Aluminum & Copper Base

Meteor Foundry Company Ltd.
1730 Bonhill Road
Mississauga, Ontario
L5T 1C8
Tel. (416) 678-2890

Aluminum & Zinc Base

Mills Metal Industries Ltd.
99 Ashley Street
Hamilton, Ontario
L8L 7W1
Tel. (416) 523-5133

Aluminum & Copper Base

Nelson Bronze Limited
73 Hincks Street
New Hamburg, Ontario
N0B 2G0
Tel. (519) 662-3660

Aluminum & Copper Base

Niagara Bronze Limited
P.O. Box 838
4248 Broughton Avenue
Niagara Falls, Ontario
L2E 6V6
Tel. (416) 356-2655

Aluminum & Copper Base

Non-ferrous Castings Ltd.
1821 Mattawa Avenue
Mississauga, Ontario
L4X 1K6
Tel. (416) 279-1316

Aluminum & Copper Base

NF Castings Ltd.
5868 Ramsey Road
P.O. Box 51A
Niagara Falls, Ontario
L2E 6X8
Tel. (416) 354-8559

Copper Base

Peninsula Alley Inc.
110 Ormond Street South
Thorold, Ontario
L2V 4J6
Tel. (416) 227-4011

Aluminum & Copper Base

Port Arthur Shipbuilding Company
P.O. Box 2690
Thunder Bay, Ontario
P7B 5G2
Tel. (807) 683-6261

Aluminum & Copper Base

Rahn Metals & Plastics Limited
P.O. Box 168
141 Regina Street
North Bay, Ontario
P1B 8H2
Tel.

Aluminum & Copper Base

Ramsden Manufacturing Ltd.
P.O. Box 4003, Station C
130 Oakland Avenue
London, Ontario
N5W 5G9
Tel. (519) 45-1721

Aluminum

Riverside Brass & Aluminum Foundry
175 Waterloo
New Hamburg, Ontario
N0B 2G0
Tel. (519) 662-2500

Aluminum & Copper Base

Joseph Robertson Foundries Ltd.
32 Milford Avenue
Toronto, Ontario
M6M 2V8
Tel. (416) 249-7624

Aluminum & Copper Base

Saltfleet Aluminum Foundry Ltd.
328 Lake Avenue North
Hamilton, Ontario
L8E 3A2
Tel. (416) 561-0033

Aluminum Base

Standard Brass & Aluminum Foundry Ltd.
550 York Road
P.O. Box 215
Guelph, Ontario
N1H 6J9
Tel. (519) 822-9971

Aluminum & Copper Base

Stoermer Bell & Brass Foundry
R.R. 2, P.O. Box 2
Breslau, Ontario
N0B 1M0
Tel. (519) 648-2281

Aluminum & Copper Base

Summerstown Metals Ltd.
Summerstown, Ontario
K0C 2E0
Tel. (613) 931-1110

Aluminum & Copper Base

Supreme Casting & Tooling
1995 Kipling Avenue
Rexdale, Ontario
M9W 4J4
Tel. (416) 743-6731

Aluminum & Copper Base

Supreme Aluminum Industries Ltd.
Presto Division
953 Sandy Beach Road
Pickering, Ontario
L1W 1Z5
Tel. (416) 691-2141

Aluminum & Copper Base

A.H. Tallman Bronze Co. Limited
P.O. Box 5014
2220 Industrial Street
Burlington, Ontario
L7R 3Y8
Tel. (416) 637-3491

Aluminum & Copper Base

Vernon Manufacturing Co.
P.O. Box 88
Black Diamond Road
Belleville, Ontario
K8N 4Z9
Tel. (604) 545-2175

Aluminum & Copper Base

Welland Iron and Brass Limited
130 Niagara Street
Welland, Ontario
L3C 1J3
Tel. (416) 735-5676

Aluminum & Copper Base

Wilson Brass & Aluminum Foundries Limited
205 Nantucket Boulevard
Scarborough, Ontario
M1P 2P2
Tel. (416) 755-5566

Aluminum & Copper Base

Woodings-Railcar Ltd.
P.O. Box 1540
Prescott, Ontario
K0E 1T0
Tel. (613) 347-2483

Aluminum & Copper Base

Appendix V. Survey Form

Gallagher+Associates
Industrial Marketing and Management Consultants
10 Price Street, Third Floor
Toronto, Ontario M4W 1Z4
(416) 961-2925

ONTARIO FOUNDRY STUDY, 1986

GENERAL INFORMATION

This study has been commissioned by the Ontario Ministry of Northern Development and Mines to examine the Province's foundry industry. It is supported by the Canadian Foundry Association. It is the first comprehensive study of Ontario Foundries since 1978.

Please prepare your response and await a telephone call from one of our consultants within 2 weeks — Gallagher & Associates, Ernst & Whinney, and Robert Shnay and Associates. Do no mail — we shall collect your responses by telephone.

Your response will be treated in confidence and only aggregated totals will be published.

Information obtained will be used to evaluate the concerns and needs of the foundry industry on a range of government policy and industry issues. Participants will receive a copy of the report on survey findings.

COMPANY .....

ADDRESS .....

.....

.....

TELEPHONE _____ TELEX .....

RESPONDENT(S):

NAME _____ TITLE .....

_____ .....

_____ .....

TYPE OF FOUNDRY:

Ownership		Moulds		Cores		Metal	
* Captive	____	Green Sand	____	Oil Sand	____	Steel	____
Independent	____	Air-set	____	CO_2	____	Iron	____
If captive, outside work		CO_2	____	Shell	____	Non-Ferrous	____
____ %		Shell	____	Other Organic Binder	____		
* Owned by a casting buyer or user.		Ceramic	____	Ceramic	____		
		Permanent	____	Permanent	____		

1. **COMPANY DESCRIPTION & FACILITIES**

1.1 Is the attached Federal government (DRIE) directory information on your company still accurate? If "NO" please correct. Yes ____ No ____

1.2 How many full-time employees on average in 1985 _____ 1980 _____

1.3 What is overall plant capacity in tons (or lbs) of good metal output for year 1985 _____ 1980 _____

2. **FOUNDRY MARKETS AND OUTPUT**

			% Captive
2.1	Please provide (approximate) output shipments in tons (or lbs) of good metal:	1985 _____	_____
		1980 _____	_____
2.2	Your forecast for	1990 _____	_____
2.3	Average $ realization per ton (average price per ton):	1985 _____	
		1980 _____	
		1990 _____	

2.4 Output by size of casting, 1985:

	% of Total		% of Total
0 — 50 lb	_____	500 — 1000 lb	_____
50 — 100 lb	_____	over 1000 lb	_____
100 — 500 lb	_____	Total	100

2.5 Major customer breakdown (% total output in tons):

	1985	1990
Automotive / Truck	____ %	____ %
Railway	____ %	____ %
Marine	____ %	____ %
Other Transportation	____ %	____ %
Municipal / Construction	____ %	____ %
Mining	____ %	____ %
Forest Products / Pulp	____ %	____ %
Valves / Pumps	____ %	____ %
Other Machinery/ Equipment	____ %	____ %
Plumbing	____ %	____ %
Appliance	____ %	____ %
Other Electrical	____ %	____ %
All Other	____ %	____ %
(specify)	_____	
	_____	

2.6 Output by type of metal & process, 1985:

		% of Total	% Sand Cast
Iron:	Gray	_____	_____
	Ductile	_____	_____
	Malleable	_____	_____
	Alloy	_____	_____
	Other	_____	_____
	(specify)	_____	_____
Steel:	Carbon	_____	_____
	Manganese	_____	_____
	Low Alloy	_____	_____
	High Alloy (stainless)	_____	_____
Non-Ferrous:	Copper-based	_____	_____
	Aluminum	_____	_____
	Magnesium	_____	_____
	Zinc	_____	_____
	Zinc-Aluminum Alloys	_____	_____

2.7 Output shipments by destination, 1985:

	% of Total		
Ontario	_____	United States	_____
Eastern Canada	_____	Other Export	_____
Western Canada	_____		_____
		Total	100

2.8 Market Trends — Commentary:

2.8.1 Major Threats:

i.e. Imports, Material Substitutions, Equipment/Process Obsolescence, Other — Describe:

_____

_____

_____

2.8.2 Major Opportunities:

i.e. U.S. / Other Exports, New Applications, Technology Improvements, Other — Describe:

_____

_____

_____

2.9 Investment Intentions:

($'000)	Actual Investment 1981 — 1985	Investment Intentions 1986 — 1990
Melting		
Molding		
Sand System		
Material Handling and Other Equipment		
Land & Buildings		
Total		
Capacity Increase (tons or lbs)		

Comments _____

Diversification / Expansion / Productivity _____

Financing / Profitability _____

3. SAND / MINERAL USAGE

3.1 Sand Consumption and Forecast:

*Sand Type / Source	AFS Fineness No.	Application	Annual Consumption ('000 tons) 1980	1985	1990

* Indicate if pre-mixed sand and binder, etc.

Comments — Explain changes not in accordance with metal output _____

3.2 Sand Economics (1985 basis):

3.2.1 Approximate Costs / ton:

Type Sand	Cost at Source	Shipping Cost	Shipping** Method

* Ship, Rail, Truck / Bulk, Bagged

3.2.2 Present Reclamation System? Yes _____ No _____

3.2.2.1 Capacity (tons / year) _____

3.2.2.2 Type System: Mechanical _____

Thermal _____

Chemical _____

3.2.2.3 Average % Recovery _____

3.2.2.4 Average cost of recovery ($ / ton) _____

3.2.3 Approximate sand cost per ton of good metal output _____

3.2.4 U.S. competitors sand cost per ton of good metal output _____

3.3 Binder Consumption & Forecast:

Binder Type* / Source	Annual Consumptions (tons) 1980	1985	1990

* Indicate if blends, etc.

Comments _____

3.4 Binder Cost / ton:

Binder Type / Source	Cost at Source	Shipping Cost	Shipping Method

3.5 Refractory Materials — Consumption & Forecast:

Type / Brand / Source	**Applications	Annual Consumptions ($ or lbs / year) 1980	1985	1990

** Indicate Furnace Type & Size, etc.

Comments _____

3.6 Fluxes and other Minerals — Consumption & Forecast:

Type / Trade Name	**Application	Annual Consumptions (tons or lbs / year) 1980	1985	1990
Limestone				
Dolomite				
Feldspar				
Graphite				
Others				

Comments _____

4. ONTARIO MINERAL OPPORTUNITIES

4.1 Ontario Sourced Minerals: Estimated % of total purchases:

Sand _____ % Refractories _____ %

Binders _____ % Fluxes _____ %

4.2 Your major mineral suppliers are:

Name	Location	Type of Minerals Purchased

4.3 Would you like to see centralized sand reclamation?

Appendix VI. Bibliography

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